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ON'S

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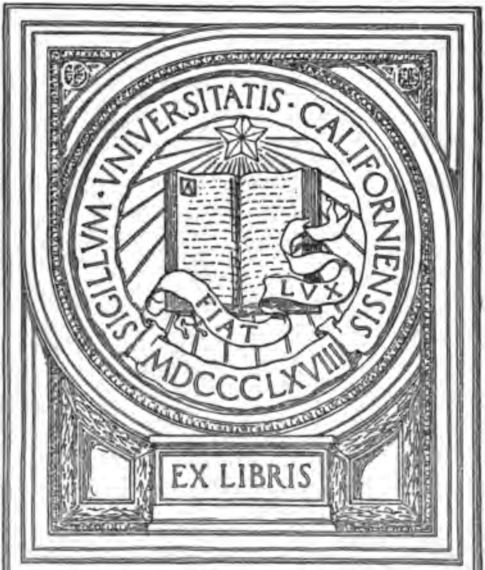

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FOR

ACADEMIES AND SCHOOLS.

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TO USE EITHER WITH OR WITHOUT THE AUTHOR'S

LARGE MAPS.

BY H. MATTISON.

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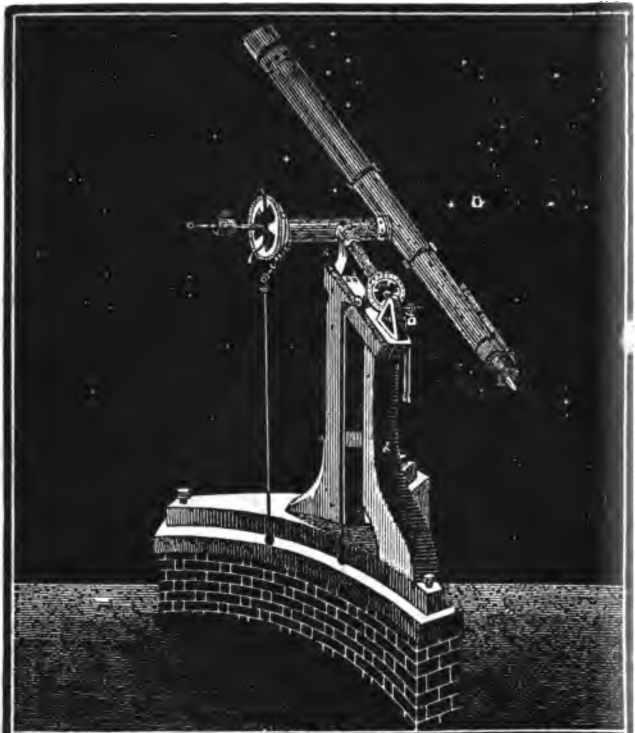

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PREFACE.

The present is, emphatically, an age of *utility*. However profound and accurate a book may be, its career will be brief and its circulation limited, unless it is eminently *practical*, and wisely adapted to its purpose. Hence it often happens, that persons of undoubted abilities as men of learning, have utterly failed in their attempts to produce available text-books in their respective departments of study.

Experience as a teacher, and tact as a compiler, are as important to the author of a school-book, as a knowledge of the subject upon which he writes. And even with all these endowments, few writers of elementary works are satisfied with their own productions till actual use in the school-room has shown wherein they are defective, or wanting in adaptation, and of what improvements they are capable. Hence almost every new school-book is "revised and improved," before it passes to a second edition.

The Elementary Astronomy and Astronomical Maps have now been before the public about eighteen months, during which time about *one thousand sets* of maps, and *ten thousand* copies of the book have been sold. These have gone into use in almost every state of the Union, and every grade of schools, from the Common School to the University. One set of maps, and a supply of books, were ordered by a Scotch lady, who had used the work in her own seminary in this country, to be used in a model school in Edinburgh, Scotland.

During the past year both the author and publishers have taken special pains to ascertain the views of *practical teachers*, who were *actually using the work*, and to obtain any suggestions which might be of service in rendering future editions more perfect and complete; and the unanimity and cordiality with which all such have commended the work, is truly gratifying and encouraging. A few alterations and improvements have been suggested, by some of which we have endeavored to profit.

Soon after the Second Edition was published, we were requested by teachers in Philadelphia and elsewhere, to prepare a suit of appropriate *Questions* on the Lessons. Accordingly, these appear in the

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Third Edition, in the form of an Appendix, and are still continued. They can, therefore, be used or not, at the discretion of the teacher.

To adapt the work to private learners, and to schools that cannot purchase the large maps, it is now issued with the large maps in miniature, interspersed among the lessons. These being exact copies of the originals, though upon a smaller scale, we have not only a magnificent set of charts for lectures and illustrations in the school-room, but each learner has a set of *the same maps* in his text-book, and can, therefore, pursue his studies either with or without the large maps, according to circumstances. The text, however, has not been altered; so that the book is still perfectly adapted to the large maps, and can be used with former editions, as if it had not been illustrated.

In a few instances the language of the book necessarily supposes the large maps to be in view, as on pages 32 and 201; but these cases are rare. As the large and small maps are the same, if the text is adapted to one, it must be to both.

The diagrams are inserted where they are first referred to, and are made to face the right, so as to be easily kept in view while studying the lessons that follow.

It is confidently believed that the peculiarities of this work are such as will commend it to general favor, and secure for it increasing popularity, and an enviable and lasting reputation.

1. In the first place, the *method* or *plan* of the work is eminently original. "One thing at a time," and "every thing in its place," have been the author's mottoes. It begins at home, or with the Solar System, and ends in the more distant or Sidereal Heavens. The Earth is treated of astronomically, or as a planet; and instead of digressing when we come to her, to consider her Moon, and the phenomena of Eclipses and Tides, these subjects, and all others pertaining to the secondary planets, are reserved for their appropriate places. Tides and Eclipses are by no means peculiar to our globe; why, then, should we sacrifice a philosophical classification, and foist in the Moon, with the subjects of Tides and Eclipses, before we have done with the primaries?

Another prominent feature in the arrangement, and one that will please every practical teacher, is, that the *facts of the science* are *classified*. Instead of naming a planet at the head of a lesson or chapter, and then giving its distance, magnitude, density, velocity, period, &c., all mingled together upon the same page, violating the laws of association, and setting at defiance the efforts of memory, all facts of the same kind are here classed together; so that the whole science is reduced to system and order. For instance, when the Primary Planets are taken up, the first lesson following is devoted to their *names* and *astronomical symbols;* the second to their *distances*, &c., so that their temperature, magnitudes, densities, periods, seasons, &c., constitute so many distinct lessons; consequently, the facts can not only be read, but *learned* and *remembered.*

2. A second characteristic of the work is, that it is more fully illustrated than any other work, of the same form, that has ever been published in this country. And yet it is not a mere picture-book, in which a noble science has been trifled with, and sacrificed to a desire to catch the eye, and sell the book. The idea of devoting every other page of a scientific work exclusively to illustrations, and at the same time doing any kind of justice to the subject on the intermediate pages, is altogether chimerical. It would be too much like a farm, one-half of which was devoted to a flower-garden; or like some of our illustrated holiday-papers.

3. The leading design being to furnish an available text-book of Astronomy for Common Schools and Academies, as well as for private students, the author has confined himself mainly to what may be called the *facts* of the science, or in other words, to the *results* which have been arrived at by the labors of the observatory and the researches of the mathematician. The structure and use of instruments, and the calculations and processes by which the facts of the science are arrived at, are designedly omitted. These may be necessary in text-books for our higher institutions of learning, but they can never become legitimate subjects of primary instruction. For similar reasons, the mythological history of the science has been discarded.

4. We have adapted the work to the present state of the science by embodying the statistics of several *new planets*, recently discovered, the recent observations of Lord Rosse upon the Moon and the distant Nebulæ, and the sublime and almost overwhelming announcement of Mädler in regard to the "Central Sun."

5. When used in connection with the large maps, the work combines all the advantages of blackboard illustrations, with the most patient study of a text-book. All the diagrams in the book are found in the corresponding maps, upon a very large scale, so that every explanation from the maps, by the teacher, serves to render the diagrams in the book more interesting and intelligible. Another striking advantage of this method of teaching Astronomy is, that whatever illus-

trations are given by the teacher, benefit the whole class alike, without the labor of repetition to each scholar, over a diagram in the book. This saving of time and repeated explanations to different pupils, will be readily appreciated by every practical instructor. Again, many of these drawings are *entirely original*, and in the opinion of competent judges, better calculated to convey a correct and permanent idea to the mind, than any that have heretofore appeared.

6. Though adapted to use with the series of large maps, it is, at the same time, complete in itself, and can be used as well independently of them as if it had no connection with them whatever. This is an important advantage.

7. To all these we may add that, all things considered, it is the *cheapest* text-book of Astronomy that has ever been published in America. A class of thirty scholars can be supplied at retail with a set of the large maps, and a book for each for $30. A school of 100 can procure a set of maps and a book for each pupil for $65. If procured at wholesale prices, a set of maps for the school-room, and a book for each pupil, would cost less than fifty cents per scholar ; and the more scholars, the less the expense to each. Where, then, we ask, can the same facilities for acquiring a knowledge of Astronomy be procured for the same money? We commend this consideration especially to those having charge of large schools in our cities and elsewhere.

Such are some of the peculiarities of the ELEMENTARY ASTRONOMY; and upon these we can safely rest our claims to public patronage, in sending it forth to the world. In its preparation for the press, the author has availed himself of all the helps within his reach. He has consulted all the books upon the subject that were available in this country, as well as many practical teachers, and gentlemen of acknowledged scientific abilities. But while on the one hand he has used books as writers generally use them, namely, as sources of knowledge, and has advised with men of learning and experience in regard to many particulars, the author feels bound, in justice to himself, to claim for his work a good degree of originality; and to say, that whether good or bad, it is, in the main, his own, and not the work of another.

It is only necessary to add, that the statistics in the tables are generally given in round numbers, and according to what were considered the highest authorities.

NEW YORK, *Jan.* 1, 1849.

TO TEACHERS.

There are several ways in which this work may be used to advantage.

1. It may be studied precisely like any other text-book, and the pupil examined by the printed, or by extemporaneous questions. This is the usual method in those schools which have not the large maps, and in academies and seminaries where the pupils study in their rooms, and see the large maps only in the recitation-room.

2. Wherever the large maps can be obtained, and the pupils all study in the same room, and only during school hours, Astronomy should be made a *general exercise* two or three times every week. The maps to which the lessons refer, should be suspended on the south side of the room, if practicable, (to answer to the natural position of many of the objects in the heavens,) and the lesson studied with constant reference to the maps. They are so much more attractive and imposing, and the figures so much more distinct and prominent than the cuts in the book, as to give them a decided advantage over all ordinary illustrations. They should, therefore, be procured wherever practicable, and used in connection with this work.

3. A third method of using the work, is to use it *as a reading-book* two or three times a week, either with or without the large charts. If these are in the school, they should be suspended before the class during the exercise. By this method the pupil will learn to pronounce scientific terms correctly, to read figures with facility, to read with attention, and to remember what he reads. Besides, no extra *time* will be required. The pupil is learning to read, and at the same time studying a science. By the use of the maps the teacher can illustrate the lessons as he goes along, and a wholesome interest will be sustained throughout. The questions in the Appendix will be found convenient in reviewing the lessons. Teachers will find this an efficient and delightful method of teaching Astronomy.

4. Several of the tables in the first part of the work should be committed to memory; such as the names, distances, magnitudes, &c., of the primary planets. If the teacher prefer, they may be learned by concert recitations.

5. The astronomical signs in Lesson 7th should be drawn upon the blackboard by the learner, and explained. It would also be useful for him occasionally to draw maps of different celestial objects, from memory.

6. In some cases, the whole subject may be presented orally by the teacher, in a series of evening lectures, following the course of the book; but this should rather be in *addition* to the regular study during school hours, than a substitute for it.

7. After all, much will depend upon the judgment and ingenuity of the teacher, and the interest he takes in the subject. Sound learning can never be acquired, by any mode of teaching, without thought and attention. Neither can any particular course be struck out that will be adapted to all kinds of schools, and to every part of the country.

8. To such teachers as have never studied this science, (and there are some of this class,) we would say that the work is specially adapted to your circumstances. It is strictly elementary, no extraneous and abstruse matters darken its pages, and it is not so voluminous as to require a year to go through it. You will find no difficulty whatever in teaching the science with this work, even though you have not previously taught it; and a class in this delightful and sublime science will be the surest means of adding to your present intellectual stores, a knowledge of this important branch of study. If any new motive be necessary, let it be remembered that no new study is so rapidly going into the primary schools of the country, as that of Descriptive Astronomy; and the time is not far distant when it will be required to be taught in every school-house in the land. Be encouraged, then, to enter upon this study. Organize your class at once, and launch out *now* for a knowledge of those fleets of worlds that sail the upper deep. If entered upon in the spirit of a *teacher*, your progress will be rapid, your voyage delightful, and success certain.

With these suggestions, the work is now committed to your hands. Having been formerly identified with you as a practical teacher, the author expects the co-operation of his professional friends, in rendering the work useful to the rising generation, and in promoting the interests of that noble science to which it is devoted.

☞For a description of the Large Maps, prices, &c., see Circular at the end of the Book.

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INTRODUCTION.

Lesson 1.

ASTRONOMY—ITS NATURE AS A SCIENCE.

Science is knowledge systematically arranged, so as to be conveniently taught, easily learned, and readily applied.

Astronomy is that science which treats of the names, distances, magnitudes, and motions of the heavenly bodies—the Sun, Moon, Planets, Comets, and Fixed Stars—and the laws by which they are governed.

All who are not deprived of the blessing of sight have seen the sun, moon, and stars. Indeed they are very familiar objects. Now, by carefully observing their appearances, and watching their movements for a short time, every learner may discover or establish the following facts for himself, viz. :—

1. The Sun and Moon appear nearly of a size, and much larger than any other bodies that we see in the heavens.

2. The Sun sheds a strong and brilliant light upon the earth, while the light of the moon is pale and feeble.

3. The Sun and Moon are sometimes near each other, as when the new moon is first seen in the west, while at other times, the moon rises in the east just as the sun goes down.

4. When the Moon is first seen east of the sun, she is very slender; but as she falls behind and separates from the sun, she grows larger and larger till she becomes a "full moon;" after which she grows smaller

and smaller till new moon again. The horns of the new moon point to the east, while those of the old moon point to the west.

5. It is easy to see, by watching the moon for only one or two nights, that she is actually moving eastward as respects the stars; and she sometimes runs over, or seems to cover up one, and put it out for a time as she goes along.

6. Everybody has noticed the dark lines and spots upon the surface of the Moon, as if some one had attempted to draw an outline map of some new country upon her face, showing its various islands, continents, and seas.

7. Most people have seen what is called an *eclipse;* or in other words the partial or total darkening of the sun or moon, as if some large object was covering them up.

8. The stars differ very much in their apparent size—some appearing large and bright, while others are so small and faint as to be scarcely perceptible.

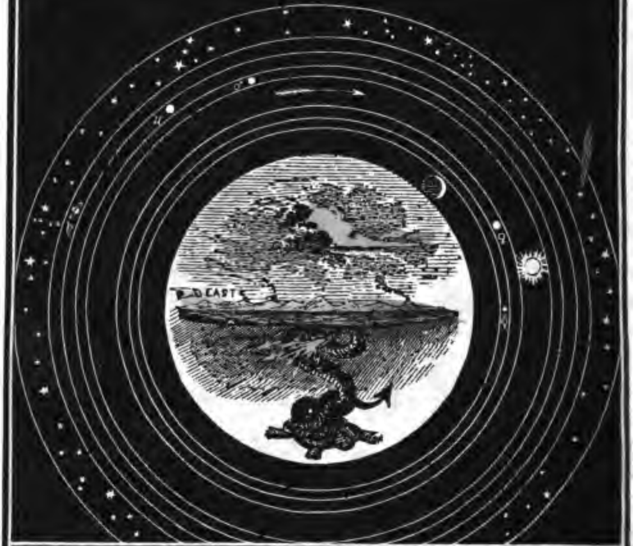
9. Most of the stars seem to keep the same distance from each other, and to occupy the same positions with reference to each other from age to age. But there are a few that are constantly wandering along eastward, as it were from star to star, till, like the Moon, they traverse the whole circuit of the heavens. During this journey, they sometimes stop for a while, and even fall back westward, but they soon resume their route again with an accelerated motion, and hasten eastward over the celestial concave.

10. One star at least is west of the sun for a time, and rises before him, on which account it is called the *Morning Star*. But this same star, may at other times, be seen east of the sun. At this time she may be seen in the west after the sun goes down, and is then called the *Evening Star*.

11. The stars in the northern portions of the heavens *never set*, but seem to revolve around what is called the North Pole star, from night to night, and from year to year. By ranging by a stake or some other permanent

MAP No.1.

PTOLEMAIC THEORY OF THE STRUCTURE OF THE UNIVERSE.



THIS MAP ILLUSTRATES

THE ANCIENT SYSTEM OF ASTRONOMY. . . . . . P. 15–17

THE FALSITY AND ABSURDITY OF THE PTOLEMAIC THEORY. P. 17–18 object, on a clear evening, it will be seen in a short time that all the stars below the North Pole star seem to be moving *eastward*.

12. During the winter, the sun is quite low down in the south; but in June and July, he is almost directly overhead at twelve o'clock, even as far north as the United States. These, and many other curious things respecting the heavenly bodies, may be observed with the naked eye, or without the aid of telescopes. It was in this way that the ancients studied astronomy. By carefully watching the heavens, they learned one fact after another, respecting the sun, moon, and stars, and when these facts were put together and arranged in systematic order, they constituted the *Science of Astronomy*.

Lesson 2.

ANCIENT HISTORY OF ASTRONOMY—THE PTOLEMAIC THEORY.

(Map 1.)

The oldest records of astronomical science are found in the Holy Scriptures. We there read of the creation of the sun, moon, and stars, and the commencement of their revolutions. In the Book of Job, which was written fifteen hundred years before Christ, we read of "*Arcturus*, *Orion*, and *Pleiades*,"—stars or clusters of stars that bear the same name at the present day. We are here taught, also, that our world does not rest upon some vast and strong foundations, but that the Almighty "hangeth the earth upon nothing."

The prophet Amos speaks of the "seven stars and Orion," seven hundred and thirty-three years before Christ, and of the phenomena of day and night.

The Greek philosopher, *Pythagoras*, taught astronomy about five hundred years before Christ, and the Egyptian philosopher, *Ptolemy*, in the second century of the Christian era. Ptolemy constructed a regular system or theory of astronomy, by which he proposed to account for all the appearances and motions of the heavenly bodies.

The PTOLEMAIC SYSTEM, so called from Ptolemy, its author, is the subject of Map No. 1. It represents the earth as located in the centre of the universe; as being perfectly at rest; as a plane instead of a globe; and as inhabited only on one of its sides. Some supposed the earth to float upon an abyss of waters; while others believed that it rested upon the head of an enormous serpent or dragon, as represented on the map. Ptolemy taught, also, that the sun, moon, planets, and stars revolved around the earth, from east to west, as they appear to do, every twenty-four hours. To account for their passing over the earth without falling down upon its surface, it was supposed that the heavenly bodies were supported by vast *arches* or *hollow spheres*, in which they were firmly set like a diamond in a ring.

But as the sun, moon, planets, and stars were not all at the same distance from the earth, it was supposed that there were several of these spheres placed one above another—that the Moon was in the first, Mercury in the second, Venus in the third, the Sun in the fourth, Mars in the fifth, Jupiter in the sixth, Saturn in the seventh, and the Fixed Stars in the eighth. The ancients had no knowledge of Herschel, or Le Verrier.

Mercury, Venus, and the Moon, were placed in the three lower spheres, because they were sometimes seen to pass between the earth and the sun. But Mercury and Venus sometimes go before the sun, and sometimes follow after him. To account for this, it was supposed that besides the great circle of the heavens around which they passed daily, they had other smaller circles within their respective spheres, in which they revolved at the same time. These the ancients called *epicycles*. They may be seen on the Map, in the second or sphere of Mercury.

To account for the rapid westward motion of these ponderous spheres, it was believed that the necessary moving power was applied in some way to the upper sphere, above the fixed stars; and that this sphere communicated its motion to the one immediately beneath or within it, and so on down to the lower sphere. This, it was thought, moved slower than the rest, as the moon constantly fell back of the sun. To allow the light of the stars to pass down to the earth, it was supposed that the several concentric spheres rising one above another, were made of the finest *crystal*, and were perfectly transparent. The space above the fixed stars was designated as the blissful abode of departed spirits.

On the map, the spaces *between* the white circles represent the several crystalline spheres. The sun and moon are represented as going down in the west, the moon having fallen a little behind the sun, as when we first see the new moon. Mercury and Venus are near the sun, as they always are, and Mars, Jupiter, and Saturn on the left. On the right is seen a *comet* passing down towards the sun.

Such is the *Ptolemaic Theory* of the structure of the Universe.

Lesson 3.

DIFFICULTIES OF THE PTOLEMAIC THEORY.

(Map 1.)

Besides the clumsiness of the machinery, it was attended by numerous difficulties which its supporters could never explain or obviate.

1. It could never determine what upheld the earth. Rocks and mountains could not float upon water; and if they could, what upheld the water? Some imagined that the earth was upheld by a huge *serpent*, resting upon the back of a *tortoise*, as represented in the map. But what upheld the tortoise?

2. It represented many very large bodies, as the sun and some of the planets are now known to be, as revolving around the earth, a comparatively small one.

3. It adopted the most difficult and unreasonable plan for lighting and warming the earth, and producing day and night. Taking the sun around the earth every twenty-four hours, was like carrying a fire around a

person who was cold and wished to be warmed; instead of his turning himself to the fire as he pleased.

4. The Ptolemaic theory would require a motion inconceivably rapid in all the heavenly bodies. As the sun is ninety-five millions of miles from the earth, the entire diameter of his sphere would be one hundred and ninety millions of miles, and its circumference about six hundred millions. Divide this distance by twenty-four—the number of hours in a day—and it gives *twenty-five million miles an hour;* or sixty-nine thousand four hundred and forty-four miles per second, as the velocity of the sun!

This theory gives a still more rapid motion to Mars, Jupiter, Saturn, and the fixed stars. It would require the nearest of the latter to move at the rate of near *fourteen thousand millions of miles per second,* or seventy thousand times as swift as light, in order to accomplish its daily course.

But with all these difficulties in its way, the Ptolemaic theory was generally believed till about the middle of the sixteenth century, or three hundred years ago.

Lesson 4.

THE COPERNICAN SYSTEM.

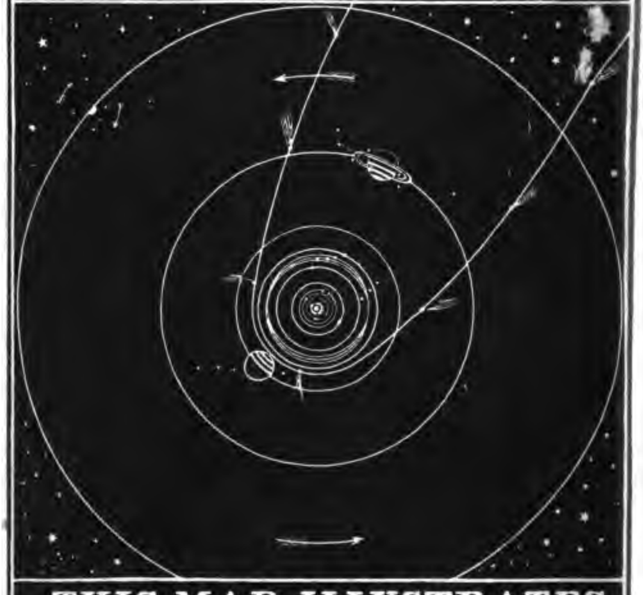
(Map 2.)

About the year 1510, *Nicholaus Copernicus,* of Prussia, taking some hint perhaps from the writings of *Pythagoras,* discovered what is now generally received as the true theory of astronomy, and called after its author the *Corpernican System.*

The COPERNICAN SYSTEM attributes the apparent daily motion of the sun, moon, and stars from east to west, to the actual motion of the earth on its axis from west to east. Though the heavenly bodies *seem* to move, yet we often transfer our own motion, in imagination, to other bodies that are at rest; especially when we are carried rapidly along without effort, as in a carriage, steamboat,

MAP No. 2.

THE COPERNICAN THEORY OF THE SOLAR SYSTEM.



THIS MAP ILLUSTRATES

THE MODERN, OR COPERNICAN SYSTEM, ... P. 18-19.
THE RELATION OF THE SOLAR SYSTEM TO THE UNIVERSE, . . P. 19-20.
THE CLASSIFICATION OF THE SOLAR BODIES, ... P. 21.
THE POSITION OF THE SOLAR BODIES IN THE SYSTEM, THEIR . . . . RELATIVE DISTANCES, MAGNITUDES &c. . . . P. 22-25-31-32
THE CENTRIPETAL & CENTRIFUGAL FORCES, ... P. 36
THE NUMBER, DISTANCES & MOTIONS OF THE . . . . . . SECONDARY PLANETS. . . . . P. 93-103-102.

or railway car. It places the sun in the centre of a system of worlds, of which the earth is one. It gives them a revolution around their common centre, by which the seasons are produced; and another upon their axes, producing day and night. It accounts for all the motions of the heavenly bodies, and harmonizes the whole system of nature.

The *Copernican System* is represented in Map 2. In the centre is seen the sun, in a state of rest. Around him, at unequal distances, are the planets and fixed stars, the former revolving about him from west to east, or in the direction of the arrows. The white circles represent the *orbits*, or paths, in which the planets move around the sun. On the right is seen a *comet* plunging down into the system around the sun, and then departing. This is the *Copernican Theory* of the solar system.

> "O how unlike the complex works of man,
> Heaven's easy, artless, unencumber'd plan!"

The truth of the Copernican theory is established by the most conclusive and satisfactory evidence. Eclipses of the sun and moon are calculated upon this theory, and astronomers are able to predict thereby their commencement, duration, &c., to a minute, even hundreds of years before they occur. We shall, therefore, assume the truth of this system, without further proof; and proceed accordingly to the study of the hoavenly bodies.

Lesson 5.

FIRST GRAND DIVISIONS OF THE UNIVERSE.

(Map 2.)

The material universe may be divided into two parts, viz., the SOLAR SYSTEM and the SIDEREAL HEAVENS.

The *Solar System* consists of the Sun and all the planets and comets that revolve around him.

The *Sidereal Heavens* embrace all those bodies that lie around and beyond the solar system, in the region of the fixed stars.

The relation of the one to the other may be partially understood by carefully observing Map 2. The sun and his attendant worlds are there seen *within* the fixed stars, which occupy the corners of the map, and the spaces without in every direction. If the observer were placed at a distance beyond the solar system, in any direction, he would see vast numbers of the fixed stars between it and him, as if they were scattered between the eye of the learner and every part of the map. But situated as we are, in the midst of the Sidereal Heavens, which surround us in every direction, it is not strange that the earth should seem to be in the centre of the universe.

In considering the general subject of astronomy, we shall proceed according to the foregoing classification, treating first of the SOLAR SYSTEM, and secondly, of the SIDEREAL HEAVENS.

PART I.

OF THE SOLAR SYSTEM.

CHAPTER I.

CLASSIFICATION OF THE SOLAR BODIES.

Lesson 6.

THE SUN, PLANETS, PRIMARIES, SECONDARIES, &c.

(Map 2.)

The Solar System derives its name from the Latin word *Sol*, the Sun. It includes that great lŭminary, and all the worlds that revolve around him. To distinguish these attendant bodies from others in the heavens, they will be denominated *Solar Bodies*.

The bodies of the Solar System are divided into several distinct classes.

I. The Sun is the fixed centre of the system, around which all the solar bodies revolve; and from which they receive their light and heat.

II. The Planets are those bodies that revolve around the sun, and receive their light and heat from him. The term *planet* signifies a *wanderer*, and was applied to the solar bodies because they seemed to move or wander about among the stars.

1. The planets are divided into *Primary* and *Secondary* planets.

The *primary planets* are those larger bodies of the system which revolve around the sun only, as their centre of motion. They may be distinguished on the map by their size, and also by their being in their orbits, or on the white circles.

The *secondary planets* revolve not only around the sun, but also around the primary planets, as their attendants or moons. They may easily be distinguished on the map.

2. The planets are again divided into *Interior* and *Exterior* planets.

The *interior* planets are those whose orbits lie *within* the orbit of the earth; or between it and the sun.

The *exterior* planets are those whose orbits lie *without* the orbit of the earth.

3. Five of the smaller primary planets are called *Asteroids*. They may be seen on the map near together, just above the sun.

4. *Comets* are a singular class of bodies belonging to the solar system, distinguished by their long flaunting trains of light, and also by the elongated form of their orbits.

CHAPTER II.

OF THE PRIMARY PLANETS.

Lesson 7.

NAMES AND SIGNS OF THE PRIMARY PLANETS.

(Map 2.)

The *Primary Planets* are thirteen in number.* They are distinguished in astronomical books by certain characters or signs, which are used to represent their respective planets. The names of the planets and their symbols are as follows:

Mercury,	☿	Vesta,	⚶	Jupiter,	♃
Venus,	♀	Astræa,	⯙	Saturn	♄
Earth,	⊕	Juno,	⚵	Herschel,	♅
Mars,	♂	Ceres,	⚳	Le Verrier,	⯉
		Pallas,	⚴		

---

* Four new Asteroids have recently been discovered, of which, however, very little is known. They are called *Flora*, *Iris*, *Metis*, and *Hebe*.

Most of the planets are named after heathen gods or goddesses.

Mercury was the messenger of the gods, and the sign, ☿, is his *caduceus*, or *rod*, with *serpents* twined around it.

Venus was the goddess of love and beauty. Her sign, ♀, is a *mirror* with a handle after the ancient form.

The Earth is represented by the sign ⊖, denoting a *sphere* and its *equator;* or by ⊕, which may denote either meridians of longitude, or the four quarters of the globe.

Mars was the god of war, and his sign, ♂, is a *buckler* and *spear*.

Vesta, the goddess of fire, has the sign of an *altar*, ⚶, with a *fire* blazing upon it.

Astræa, the name of the new asteroid, signifies a *star*, and may be known by its appropriate sign, ✳.

Juno was the reputed queen of heaven; and her sign, ⚵, is an ancient *mirror*, crowned with a *star*—an emblem of beauty and power.

Ceres is so called after the goddess of grain and harvests. Her sign, ⚳, is a *sickle*, of an antiquated form.

Pallas was the goddess of Wisdom, and her sign, ⚴, is *the head of a spear*.

Jupiter, the reputed father of the gods, is known by the sign ♃. It was originally the letter Z, the first letter of the Greek word *Zeus*, the name for Jupiter, which has been changed in the course of time to its present form.

Saturn was the reputed father of Vesta, Ceres, &c. His astronomical sign, ♄, is supposed originally to have denoted a *scythe*.

Herschel, so called after Sir William Herschel, its discoverer, (also called *Georgium Sidus*, or *Georgian Star*, after George III. his patron, and *Uranus*, from a heathen divinity,) has the sign of the letter H, with a planet suspended from the cross-bar—thus, ♅. It is designed to indicate Dr. Herschel as its discoverer.

Le Verrier, the last *new planet*, so called from its discoverer, has the sign of an L and a V united, with a planet suspended from the hair line of the V—thus, . This also denotes the discoverer of the planet.*

The MOON is denoted by various signs, according as it is new, half-grown, or full—thus, ●, ◐, ○.

The SUN is represented by the sign ☉, denoting an ancient *buckler*. As the ancients kept their bucklers bright, so as to dazzle the eyes of their enemies, this instrument was selected as the appropriate emblem of the sun. It is also known by the signs and .

The five planets enclosed in braces in the table are the *Asteroids*. Mercury and Venus are the *interior* planets, and those outside the Earth's path the *exterior*.

The several planets should now be looked out upon the map, and their comparative size, distances from the sun, and appearances carefully noticed.

Mercury is placed close to the sun, and directly under him. *Venus* is also near the sun, and a little above him on the left. The *Earth* is next in order, above the sun, and a little to the right. The *Moon* and her orbit will be seen near the earth. *Mars* is on the right of the sun, and beyond the orbit of the earth. He is the first of the *exterior* planets. Above the earth are seen the five planets called *Asteroids*, viz.: *Vesta*, *Astræa*, *Juno*, *Ceres*, and *Pallas*. *Jupiter* is the large planet below the sun on the left. His surface is striped with curious *belts*, and he is attended by four secondary planets or moons. Above the Asteroids on the right is seen the beautiful planet *Saturn*. He is attended by seven moons, and surrounded by two magnificent and wonderful *rings*. *Herschel* and his six moons are placed on the left, near the upper corner of the map. *Le Verrier* could not be placed upon the map at his relative distance, but may be imagined at twice the distance of Herschel, and of about the same magnitude.

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* The Board of Longitude of Paris recommend that the new planet be called *Neptunus*, after the heathen god of the seas, with the sign of a *trident*; but we see no good reason why the name of its discoverer should be exchanged for that of an imaginary divinity. Astronomy needs no additional appendages from the Mythology of the ancients.

Lesson 8.

DISTANCES OF THE PLANETS FROM THE SUN.

(Map 2.)

Map 2 shows all the planets, except Le Verrier, at their relative distances from the sun. The scale is one hundred millions of miles to an inch. The distances of the planets in miles are as follows:

Mercury,	37	millions.	Ceres,	263	millions.
Venus,	69	"	Pallas,	263	"
Earth,	95	"	Jupiter,	495	"
Mars,	145	"	Saturn,	900	"
Vesta,	225	"	Herschel,	1,800	"
Astræa,	253	"	Le Verrier,	2,800	"
Juno,	254	"			

It is difficult to conceive justly of these vast distances. Were a body to move at the rate of five hundred miles an hour, without intermission, it would require near eight and a half years for it to pass from the sun to the nearest of these planets. To visit the earth would require over twenty-one years; and to reach Herschel over four hundred years!

Railroad cars travel at the rate of about thirty miles an hour, or a mile in two minutes. Now if there was a railroad from the sun to the orbit of Le Verrier and the orbits of the other planets were stopping-places on the route, the train would reach

Mercury,	in	152	years.
Venus,	"	264	"
Earth,	"	361	"
Mars,	"	554	"
Jupiter,	"	1,884	"
Saturn,	"	3,493	"
Herschel,	"	6,933	"
Le Verrier,	"	10,650	"

Such a journey would be equal to riding 900,000 times at the eye will be great or small, according as it is near to or distant from the observer. This is illustrated by Fig. 2. On the left is the object. To the observer in the centre the globe is 20° in diameter; but to the one on the right its diameter is but 10°. To a third observer, at twice the distance of the last, it would appear but 5° in diameter, &c. This shows why objects grow smalle in appearance as we recede from them, and larger as we advance towards them. Their apparent magnitude is increased or diminished *in proportion to the distance from which they are viewed.*

Lesson 11.

THE SUN AS SEEN FROM THE DIFFERENT PLANETS.

(Map 3.)

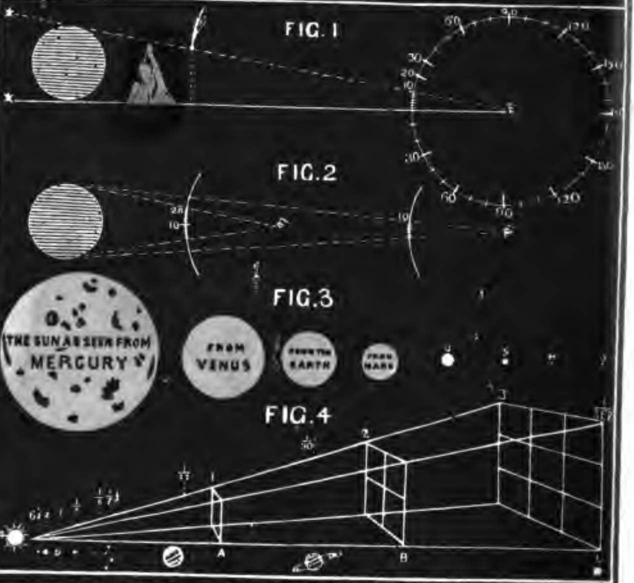
By the table of distances, (8,) and also by Map 2, it will be seen that the Sun is about twice as near to Mercury as he is to Venus. Of course, then, according to the principle illustrated in Fig. 2, his apparent diameter must be twice as great when viewed from Mercury as when viewed from Venus. From the Earth it is still smaller, and so on till we view him from the distant orbit of Le Verrier, from which he would appear but a small glimmering point in the heavens. From the fixed star Sirius, he would appear smaller than Sirius appears to us.

The relative apparent magnitude of the Sun, as seen from the different planets, is represented by Fig. 3. His angular diameter would be,

From Mercury	82½′	From Ceres	11½′
" Venus	44¼′	" Pallas	11½′
" Earth	32′	" Jupiter	6′
" Mars	21′	" Saturn	3⅛′
" Vesta	13½′	" Herschel	1⅝′
" Astræa	12′	" Le Verrier	50″
" Juno	12′		

MAP No.3.

ANGULAR MEASUREMENT-LIGHT AND HEAT OF THE PLANETS



THIS MAP ILLUSTRATES

THE SUBJECT OF MEASUREMENT BY DEGREES MINUTES AND SECONDS. . . . . P. 26

ANGULAR DISTANCES, MAGNITUDES, ALTITUDES AND VELOCITIES. . . . . P. 27, 28

THE RELATIVE APPARENT MAGNITUDE OF THE SUN, AS SEEN FROM THE DIFFERENT PLANETS. . . . . P. 28

THE PHILOSOPHY OF THE DIFFUSION OF LIGHT. . P. 29

From Mercury it is supposed that the spots on the Sun would be visible to the naked eye, as seen on the map; and from Le Verrier the Sun himself would appear but as a large and brilliant star. Let the student imagine himself as approaching the sun till it has four times its present apparent diameter, and his spots stand out in full view to the naked eye; and then let him recede from the sun, pass the earth and the orbits of Jupiter and Saturn, and retire away into space, till the sun appears but a glimmering star, and he will have some faint conception of the almost inconceivable distances of the solar bodies.

Lesson 12.

PHILOSOPHY OF THE DIFFUSION OF LIGHT.

(Map 3.)

Light always moves in straight lines, unless turned out of its course by *reflection* or *refraction*. This is represented by Fig. 4 on the map; where the light is seen passing to the right, from the sun on the left. From this law it follows that the squares A B and C in the diagram would receive equal quantities of light; but as B has four times, and C nine times the surface of A, a single square of B equal to A, would receive only one-fourth as much light as A; and a square of C, equal to A, would receive only one-ninth as much. This difference in the amount of light received is caused by the unequal *distances* of the several squares from the miniature sun on the left. The distances are marked on the upper line of light by the figures 1, 2, 3.

The rule for determining the relative amount of light received by several bodies, respectively, placed at unequal distances from their luminary, is, that *their light is inversely as the squares of their distances.* This rule, also, is illustrated by the figure. The square of 1 is 1; the square of 2 is 4; and the square of 3 is 9. Hence 1, $\frac{1}{4}$, and $\frac{1}{9}$, will represent their relative light, as already shown. The checks are designed to illustrate this rule.

Lesson 13.

LIGHT AND HEAT OF THE SEVERAL PLANETS.

(Map 3.)

By applying the foregoing rule to the *planets*, at their respective distances from the sun, we are enabled to ascertain the relative amount of light received by each; and on the supposition that their heat is proportionate to their light, we can easily determine their *average temperature*. At the bottom of the map the planets are placed at their relative distances from the sun, commencing with Mercury on the left, and extending to Herschel on the right. Immediately over each planet respectively, and near the upper line of the diagram, is marked the proportionate light and heat of each, the earth being one. They are as follows:

Mercury - - - - - -	$6\frac{1}{2}$	Juno - - - - - - - - -	$\frac{1}{7}$
Venus - - - - - - - -	2	Ceres and Pallas - -	$\frac{1}{9}$
Earth - - - - - - - -	1	Jupiter - - - - - -	$\frac{1}{27}$
Mars - - - - - - - - -	$\frac{1}{2}$	Saturn - - - - - -	$\frac{1}{90}$
Vesta - - - - - - - -	$\frac{1}{6}$	Herschel - - - -	$\frac{1}{368}$
Astræa - - - - - - -	$\frac{1}{7}$	Le Verrier - - -	$\frac{1}{1300}$

It appears, therefore, that Mercury has $6\frac{1}{2}$ times as much light and heat as our globe; Herschel only $\frac{1}{368}$, and Le Verrier only $\frac{1}{1300}$th part as much. Now if the average temperature of the earth is 50 degrees, the average temperature of Mercury would be 325 degrees; and as water boils at 212, the temperature of Mercury must be 113 degrees above that of boiling water. Venus would have an average temperature of 100 degrees, which would be twice that of the earth. On the other hand, Jupiter, Saturn, Herschel, and Le Verrier, seem doomed to the rigors of perpetual winter. Think of a region 90, 368, or 1300 times colder than the average temperature of our globe!

> "Who there inhabit must have other powers,
> Juices, and veins, and sense, and life, than ours:
> One moment's cold, like theirs, would pierce the bone,
> Freeze the heart's blood, and turn us all to stone!"

It is not certain, however, that the heat is proportionate to the light received by the respective planets, as various local causes may conspire to modify either extreme of the high or low temperatures. For instance, Mercury may have an atmosphere that arrests the light, and screens the body of the planet from the insupportable rays of the sun; while the atmospheres of Saturn, Herschel, &c., may act as a refracting medium to gather the light for a great distance around them, and concentrate it upon their otherwise cold and dark bosoms.

Lesson 14.

MAGNITUDE OF THE PLANETS.

(Map 2.)

On the large map the planets are drawn upon a scale of 40,000 miles of diameter to an inch. The Sun is represented as but a point, because he could not be placed in the map, of a size proportionate to the planets.

The diameters of the several planets are as follows:

Mercury,	3,000 miles.	Ceres,	1,600 miles.
Venus,	7,700 "	Pallas,	2,100 "
Earth,	8,000 "	Jupiter,	89,000 "
Mars,	4,200 "	Saturn,	79,000 "
Vesta,	270 "	Herschel,	35,000 "
Astræa,	unknown.	Le Verrier,	35,000 "
Juno,	1,400 "		

By carefully observing each planet as laid down on the map, it will be seen that their relative magnitudes correspond with their relative diameters as here stated.

Lesson 15.

RELATIVE MAGNITUDE OF THE SUN AND PLANETS.

(Map 4.)

The relative magnitude of the sun and planets is represented in Map 4, Fig. 1. The scale of the charts is the same as in No. 2—namely, 40,000 miles of diameter to an inch. As the sun is 886,000 miles in diameter, he is drawn $22\frac{1}{6}$ inches across, to show his true magnitude as compared with the planets. These may be seen on the right side of the map, commencing with Mercury at the top, and passing downward to Herschel. Le Verrier is opposite Herschel on the left.

The secondary planets will be seen around their primaries.

The magnitudes of the primary planets as compared with the earth, are as follows, viz.:

Mercury, - - - -	$\frac{1}{18}$	Ceres, - - - - -	$\frac{1}{135}$
Venus, - - - - -	$\frac{9}{10}$	Pallas, - - - - -	$\frac{1}{55}$
Earth, - - - - - -	1	Jupiter, - - -	1,400
Mars, - - - - - -	$\frac{1}{6}$	Saturn, - - -	1,000
Vesta, - - - - -	$\frac{1}{28000}$	Herschel, - -	90
Astræa, unknown.		Le Verrier, -	90
Juno, - - - - - -	$\frac{1}{186}$		

The *sun* is 1,400,000 times larger than the earth, and 500 times larger than all the other bodies of the Solar System put together. It would take one hundred and twelve such globes as our earth, if laid side by side, to reach across his vast diameter.

The moon's orbit is two hundred and forty thousand miles from the earth. Now, if the sun was placed where the earth is, he would fill all the orbit of the moon, and extend more than two hundred thousand miles beyond it on every side! What is a globe like ours compared with such a vast and ponderous body as the sun?

MAP No. 4.

RELATIVE MAGNITUDE OF THE SUN AND PLANETS

FIG. 1

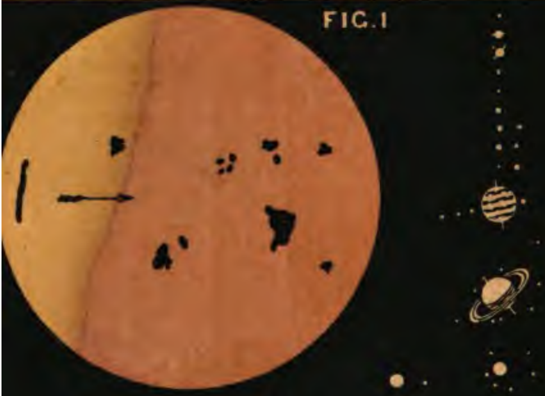
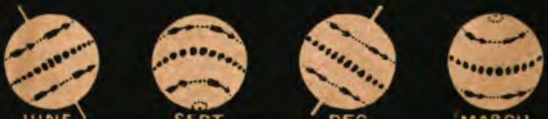


FIG. 2



JUNE. SEPT. DEC. MARCH.

THIS MAP ILLUSTRATES

THE RELATIVE MAGNITUDE OF THE SUN AND PLANETS. . . P.32

THE NUMBER, MAGNITUDE AND APPEARANCE OF THE SOLAR SPOTS. P.138-142

THE SUBJECT OF THE SUN'S REVOLUTION UPON HIS AXIS. P.142

THE CAUSE OF THE VARIOUS CHANGES AND DIRECTIONS OF THE SOLAR SPOTS. 143

THE SUBJECT OF THE SUN'S PHYSICAL CONSTITUTION P.144

Lesson 16.

COMPARATIVE DENSITY OF THE PLANETS.

By *density* is meant *compactness* or *closeness of parts*. Hence we say cork is less dense than iron, and stone is more dense than common earth. In like manner the planets differ from each other in density, or in the compactness of the substances of which they are composed.

The comparative density of the several planets, and the substances with which they most nearly agree in weight, will be shown by the following table, in which the earth is taken as the standard of comparison.

Mercury, . .	3—lead.	Saturn, . . .	$\frac{1}{10}$—cork.
Venus, . . .	$\frac{9}{10}$—earth.	Herschel, .	$\frac{1}{4}$—water.
Earth, . . .	1	Le Verrier, .	unknown.
Mars, . . .	$\frac{9}{10}$—earth.	Sun, ...	$\frac{1}{4}$—water.
Jupiter, . .	$\frac{1}{4}$—water.		

This table is one of considerable importance, and should be committed to memory. Its uses will be more clearly seen in the next lesson.

Lesson 17.

ATTRACTION OF THE PLANETS.

Attraction or *gravitation* is the tendency of bodies towards each other. By this influence substances fall to the earth, when raised from it and left without support. The *force* of attraction is what constitutes the *weight* of bodies; and its amount depends upon the quantity of matter in the bodies attracting, and their distances from each other.

From the above law of attraction it follows that large bodies attract much more strongly than small ones, provided their densities are equal, and their distances the same; and as the force of attraction constitutes the *weight* of a body, it follows that a body weighing a given number of pounds on the Earth would weigh much more on Jupiter or Saturn; and much less on Mercury or the Asteroids.

The following table shows the relative attractive force of the Sun and Planets. A body weighing one pound on the Earth, would weigh

	lbs.	oz.
On Mercury, - - -	1	1½
" Venus, - - - -	0	15
" Mars, - - - -	0	8
" Jupiter, - - - -	2	8
" Saturn, - - - -	1	5½
" Herschel, - - -	0	12½
" Le Verrier, - - -	unknown.	
" The Sun, - - -	28	5¾

A person weighing 150 lbs. on the Earth, would consequently weigh 375 lbs. on Jupiter; 4,250 lbs. on the Sun; and only 75 lbs. on Mars. The attractive force of the Asteroids is so slight that if a man of ordinary muscular strength were transported to one of them, he might probably lift a hogshead of lead from its surface without difficulty.

But the learner will notice that the attractive force, as shown in the above table, is not in strict proportion to the *bulk* of the planets respectively. This difference will be accounted for by again referring to Lesson 16, where the subject of *density* is considered. From the principles there laid down, it will be seen at once that though one planet be as large again as another, still, if it were but half as dense, it would contain no more matter than the smaller one; and their attractive force would be equal. If Jupiter, for instance, were as dense as the earth, his attractive force would be four times what it now is; and if the density of all the solar bodies was precisely the same, their attractive force, or the weight of bodies on their surfaces, would be in exact proportion to their bulk.

Lesson 18.

PERIODIC REVOLUTIONS OF THE PLANETS.

(Map 2.)

It has already been stated (3, 4, and 6) that the planets revolve around the sun. Their direction is from west to east, or towards that part of the heavens in which the sun rises. The passage of a planet from any particular point in its orbit, around to the same point again, is called its *periodic revolution;* and the time occupied in making such revolution is called its *periodic time.*

The periodic times of the planets are as follows:

Mercury,	0	years,	88	days
Venus,	0	"	225	"
Earth,	1	"		
Mars,	1	"	322	"
Vesta,	3	"	230	"
Astræa,	4	"	51	"
Juno,	4	"	134	"
Ceres,	4	"	220	"
Pallas,	4	"	225	"
Jupiter,	11	"	317	"
Saturn,	29	"	175	"
Herschel,	84	"		
Le Verrier,	164	"		"

The periodic time of a planet may very properly be called its *year;* hence, one of Herschel's years would equal 84 of ours; a year of Saturn is equal to about 30 of ours, &c.

But this difference in the length of the years of the several planets, is not owing solely to the difference in the extent of their orbits: there is an actual difference in their velocities, as will be shown in the next lesson.

Lesson 19.

HOURLY MOTION OF THE PLANETS IN THEIR ORBITS.

(Map 2.)

Mercury,	95,000	miles.
Venus,	75,000	"
Earth,	68,000	"
Mars,	55,000	"
Vesta,	44,000	"
Astræa,	42,000	"
Juno,	42,000	"
Ceres,	41,000	"
Pallas,	41,000	"
Jupiter,	30,000	"
Saturn,	22,000	"
Herschel,	15,000	"
Le Verrier,	11,000	"

Here, instead of finding the swiftest planets performing the longest periodic journeys, this order is reversed, and they are found revolving in the smallest orbits. The nearer a planet is to the sun, the more rapid its motion, and the shorter its periodic time. The reasons for this difference in the velocities and periodic times of the planets, will appear in the next lesson.

Lesson 20.

CENTRIPETAL AND CENTRIFUGAL FORCES.

(Map 2.)

The tendency of the planets towards the sun, or in other words, the mutual attractive force of the sun and planets, is called the *centripetal* force; and the projectile force, or that which impels the planets onward in their orbits, is called the *centrifugal* force. If the centripetal, or force of attraction, was suspended, the planets would fly off in straight lines beyond their present orbits, and leave the Solar System forever; and if the centrifugal force was suspended, the planets would yield to the centripetal force, and fall to the surface of the sun.

It has already been stated, in Lesson 17, that the force of attraction depended somewhat upon the distances of the attracting bodies; those nearest together being mutually attracted most. It follows, therefore, that Mercury has the strongest tendency towards the sun, Venus next, the Earth next, &c., till we get through to Le Verrier; and as the centrifugal force, which is to balance the centripetal, is created by the velocity or projectile force of the planets, that velocity must needs be in proportion to their distances respectively, from the sun; the nearest revolving the most rapidly. This we find to be the actual state of things in the Solar System. And what wisdom and skill are displayed in so adjusting these great forces, as that the planets neither fall to the sun on the one hand, nor fly off beyond the reach of his beams on the other! As it is, they remain balanced in their orbits; and steadily revolve at stated periods from age to age. "O Lord, how manifold are thy works! in wisdom hast thou made them all."

Lesson 21.

DIURNAL REVOLUTIONS OF THE PLANETS.

(Map 8.)

In addition to the motion of the planets in their orbits around the sun, they have another motion around their respective axes, producing the vicissitudes of day and night. So far as is known, the time of these revolutions, or the length of their days, respectively, is as follows:

Mercury, ...	24	hours.
Venus, ...	23½	"
Earth, ...	24	"
Mars, ...	24½	"
Jupiter, ...	10	"
Saturn, ...	10½	"

Herschel, ...	unknown.
Le Verrier, ...	unknown.
Sun, ...	25 days 14 hours.

The learner will not fail to observe the striking similarity in the length of the days of the first four of the planets; much less the very rapid motion of Jupiter and Saturn upon their respective axes. As their days are only about five hours long, the sun must seem to mount very rapidly up their heavens, and to decline as rapidly downward to their western horizon. His progress must be apparent to the inhabitants of those planets.

From the rapid rotation of Jupiter and Saturn, it follows that they must have about 875 of their days in one of our years; and as Jupiter's year is about 12 times, and Saturn's about 30 times as long as ours, it follows that the former will have about 10,500 days in his year, and the latter about 26,200.

The fact that the planets revolve upon their respective axes is ascertained by observing the motion and direction of spots on their surfaces; or, in other words, their continents and seas. For instance, in observing the sun, we discover one of his spots on his eastern limb or edge, and by watching it, find that it passes over his disc and disappears from his western limb in about 12 days and 19 hours. From this we infer that it would pass around and reappear where it was first seen, in 12 days and 19 hours longer; making the time of the entire revolution 25 days and 14 hours. It is in this way that the time of the revolution of the planets upon their axes is determined. The *effect* of the rotation of the planets in modifying their forms, will be shown in the next lesson.

Lesson 22.

TRUE FIGURE OF THE PLANETS.

The spherical form of the planets evinces the supreme wisdom of the great Creator. Were they cubes, for instance, instead of spheres, their temperature would be far

MAP No. 5.

THE ECLIPTIC. ZODIAC. SIGNS. NODES, TRANSITS. &c

FIG. 1

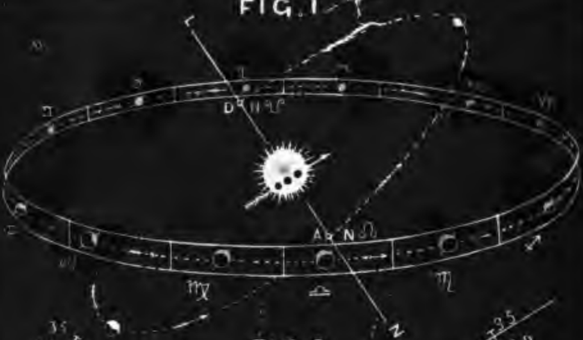
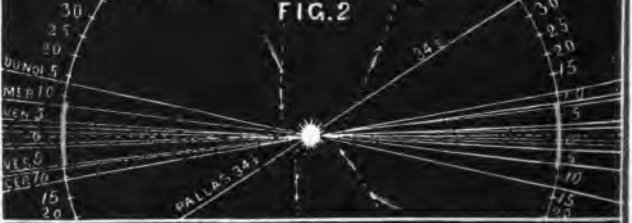


FIG. 2



THIS MAP ILLUSTRATES

THE NATURE OF THE ECLIPTIC. ZODIAC, SIGNS OF THE ZODIAC &c . 39-41

THE SUBJECT OF NODES. ASCENDING AND DESCENDING, P. 42

THE PHILOSOPHY OF TRANSITS, NODE-MONTHS &c. P. 43-46

THE INCLINATION OF THE ORBITS OF THE SEVERAL
PLANETS TO THE PLANE OF THE ECLIPTIC, P. 46

THE LONGITUDE OF THE ASCENDING NODES
OF THE PLANETS P. 48

THE SUN'S APPARENT MOTION IN THE ECLIPTIC, P. 51

less regular than it now is; the sun would rise suddenly upon a whole side at once, and as suddenly disappear at night; and the blessings of twilight, and the gradual succession of day and night, as they now transpire, would be unknown.

On the maps the planets are represented as exactly round, or spherical; but this is not their precise form. Their rapid motion around their respective axes has a tendency to depress or flatten them at their poles; and extend or widen them at their equators. Hence their equatorial diameter is considerably greater than their polar diameter; the true figures of the planets being that of *oblate spheroids*.

The difference between the polar and equatorial diameter of the planets respectively, so far as known, is as follows:

Earth, . .	26 miles.	Jupiter, . .	6,000 miles.
Mars, . .	25 "	Saturn, . .	7,500 "

Lesson 23.

THE ECLIPTIC.

(Map 5.)

The *Ecliptic* is the plane or level of the earth's orbit, indefinitely extended. Fig. 1 represents the earth in her orbit, as she would appear to a beholder placed at a distance, and elevated above the plane of the ecliptic. She is represented in perspective as appearing smaller as she grows more distant—as keeping her poles towards the same points in the heavens; and as exhibiting the phases of the moon according as we see more or less of her enlightened side. She is colored green, as she usually is through the series, to represent her vegetation. The arrows placed in her orbit show her direction.

If the student has any difficulty in getting a correct idea respecting the ecliptic, let him suppose the orbit of the earth to be a hoop of small wire laid upon a table: the surface of the table, both within and without the hoop, would then represent the plane of the ecliptic.

From the above definition and description, it will be seen that the ecliptic passes through the centre of the earth, and the centre of the sun; consequently the ecliptic and the apparent path of the sun through the heavens are in the same plane. It will be easy, therefore, to ascertain the true position of the ecliptic in the heavens; and to imagine its course among the stars on the other side of the globe.

Lesson 24.

THE POLES OF THE ECLIPTIC.

(Map 6.)

The poles of the earth are the extremities of her axis. The poles of the ecliptic are the extremities of the imaginary axis upon which the *ecliptic* seems to revolve. The ends of a rod or pointer, run through the map at the centre of the sun, would exactly represent the poles of the ecliptic.

As the ecliptic and equator are not in the same plane, their poles do not coincide, or are not in the same points in the heavens.

Lesson 25.

OBLIQUITY OF THE ECLIPTIC.

(Map 8.)

It has already been stated that the sun as well as the earth is always in the plane of the ecliptic. But he is north of the equator for six months, and south six months. It follows, therefore, that one-half the ecliptic is south of the plane of the earth's equator, and the other half north of it.

As the axis of the earth is inclined to the ecliptic 23° 28′, her equator must make the same angle to the ecliptic in the opposite direction; and the ecliptic must cross the plane of the equator obliquely. The angle of 23°

28′ thus made is what constitutes *the obliquity of the ecliptic.*

This subject will be better understood by examining the figure of the earth, and the position of her equator, as represented on the map.

Lesson 26.

THE ZODIAC.

(Map 5.)

The *Zodiac* is an imaginary belt 16° wide, namely, 8° on each side of the ecliptic; and extending from west to east quite around the heavens. It is represented on the map by the plain circles above and below the ecliptic. In the heavens the Zodiac includes the sun's apparent path, and a space of eight degrees south and eight degrees north of it.

Lesson 27.

SIGNS OF THE ZODIAC.

(Map 5.)

The great circle of the Zodiac is divided into twelve equal parts called *signs*. These divisions are shown on the map by the spaces between the perpendicular lines that cross the Zodiac. The ancients imagined the stars of each sign to represent some animal or object, and gave them names accordingly.

The names, order, and symbols of the twelve signs of the Zodiac, are as follows:

Aries, or the Ram,	♈	Libra, the Balance,	♎
Taurus, the Bull,	♉	Scorpio, the Scorpion,	♏
Gemini, the Twins,	♊	Sagittarius, the Archer,	♐
Cancer, the Crab,	♋	Capricornus, the Goat,	♑
Leo, the Lion,	♌	Aquarius, the Waterman,	♒
Virgo, the Virgin,	♍	Pisces, the Fishes,	♓

The ancient Astrologists supposed that each of these signs governed some particular part of the human body; and even in modern times people sometimes consult the frontispiece of their almanacs, to see whether the "sign" is "in the head," or "in the heart;" so as to attend to certain important affairs "when the sign is right." The idea seems to be that the word "*sign*" signifies an *omen* or *prognostication;* and that the signs of the Zodiac have some mysterious control over the destiny of man. But this fragment of heathen astrology is fast falling into disrepute; and it is hoped will soon be utterly banished from every civilized country.

Lesson 28.

NODES—ASCENDING AND DESCENDING.

(Map 5.)

Fig. 1 represents an interior planet as revolving in an orbit inclined to the ecliptic at an angle of about 45°; and as both planets revolve around the same centre of attraction, the interior planet must pass through the plane of the ecliptic twice at every revolution: once in ascending, and once in descending. These two points, where the orbit of a planet passes through or cuts the plane of the ecliptic, are called the *nodes* of its orbit. One is called the *ascending*, and the other the *descending* node. On the map A. N. is the ascending node, and D. N. the descending node. They are also denoted by the following characters, viz.: ☊ for the ascending, and ☋ for the descending.

A line drawn from one node to the other is called the *line of the nodes*, and may be seen on the map, marked L. N.

In the figure the ascending node is represented as being in the middle of Libra, and the descending in the middle of Taurus. The design is merely to illustrate the subject, without representing the actual line of the nodes of any one of the planets.

Lesson 29.

TRANSITS.

(Map 5.)

By consulting Fig. 1 it will be seen that if an interior planet was at her ascending node, and the earth on the *line* of the nodes, on the same side of the ecliptic, the planet would seem to pass over the body of the sun, as shown in the figure. This passage of a planet over the sun's disc, or between the earth and the sun, is called a *Transit.*

Mercury and Venus are the only planets that can make a transit visible to us; as all the rest are exterior to the earth's orbit, and consequently can never come between the earth and the sun. But the earth may make transits visible from Mars, the Asteroids, and Jupiter; and they in turn may make transits for the inhabitants of all exterior worlds. The principle is, that each interior planet may make transits for all those that are exterior.

But transits can never occur except when the interior planet and the earth, or planet from which the transit is seen, are both on the line of the nodes. The sun and both the planets will then be in a line, and the one nearest the sun will seem to pass, like a dark round spot, over the sun's face.

If the orbits of Mercury and Venus lay in the plane of the ecliptic, (see Lesson 23,) they would make transits whenever they were in conjunction with the sun. Even with their present inclination the same phenomenon would take place twice in every revolution, if Venus and the earth, for instance, were to start together from the line of Venus's nodes, and revolve in the same periodic time. Venus would then always make a transit in passing her nodes.

To calculate transits at any one node, we have only to find what number of revolutions of the interior planet are exactly equal to one, or any number of revolutions of the earth; or in other words, when the earth and the planet will again meet on the line of the planet's nodes. In the case of Mercury this ratio is as 87.969 is to 365.256; from which we ascertain that

7 periodical revolutions of the Earth are equal to 29 of Mercury;
13 " " " " " 54 "
33 " " " " " 137 "
46 " " " " " 191 "

Therefore transits of Mercury, *at the same node*, may happen at intervals of 7, 13, 33, 46, &c., years.

All transits and eclipses are calculated upon these principles.

Lesson 30.

TRANSITS OF MERCURY.

(Map 5.)

The following is a list of all the transits of Mercury from the time the first was observed, November 6, 1631, to the end of the present century.

1631—November 6.
1644—November 6.
1651—November 2.
1661—May 3.
1664—November 4.
1674—May 6.
1677—November 7.
1690—November 9.
1697—November 2.
1707—May 5.
1710—November 6.
1723—November 9.
1736—November 10.
1740—November 2.
1743—November 4.
1753—May 5.
1756—November 6.
1769—November 9.
1776—November 2.
1782—November 12.
1786—May 3.
1789—November 5.
1799—May 7.
1802—November 8.
1815—November 11.
1822—November 4.
1832—May 5.
1835—November 7.
1845—May 8.
1848—November 9.
1861—November 11.
1868—November 4.
1878—May 6.
1881—November 7.
1891—May 9.
1894—November 10.

By carefully examining the foregoing table it will be seen that the transits of Mercury all occur in the months of May and November. The reason for this is, that his ascending node is in the 16th degree of Taurus, and his descending in the 16th degree of Scorpio; the first of which points the earth always passes in November, and the other in May.

All the transits, therefore, that happen in November, are when Mercury is at his ascending node, and the residue are when he is at his descending node.

Again: If we take the transits in their order, as laid down in the table, they will be found not to occur at intervals of 7, 13, 33, 46, &c. years, as previously stated; but if we take those only that occur *at the same node*, we shall find them regulated according to the ratio prescribed. For example: from 1631 to 1644 is 13 years; from 1644 to 1651 is 7 years; from 1651 to 1664 is 13 years; from 1664 to 1677 is 13 years; from 1677 to 1690 is 13 years; from 1690 to 1697 is 7 years, &c. Thus far their intervals are 7 and 13 years; but they may happen at the other periods.

If we take those occurring in May we shall find them conforming to the same ratio; as previously laid down in Lesson 29.

Lesson 31.

TRANSITS OF VENUS.

(Map 5.)

8	periodical	revolutions	of the	Earth are	equal to	13	of Venus.
235	"	"	"	"	"	382	"
243	"	"	"	"	"	346	"
251	"	"	"	"	"	408	"
291	"	"	"	"	"	475	"

The line of Venus's nodes lies in the middle of Gemini and Sagittarius; which points are passed by the Earth in December and June. It follows, therefore, that transits of Venus must always happen in one or the other of these months.

The following is a list of all the transits of Venus from 1639 (the time the first was observed) to A. D. 2012.

1639—December 4.
1761—June 5.
1769—June 3.
1822—December 6.
1874—December 8.
1882—December 5.
2004—June 7.
2012—June 5.

Here it will be noticed, that the transits for December occur at intervals of 235 and 8 years; and those of June at intervals of 8, 235, and 8 years, according to the ratio previously stated.

Lesson 32.

INCLINATION OF THE ORBITS OF THE PLANETS TO THE PLANE OF THE ECLIPTIC.

(Map 5.)

Fig. 1 represents the orbit of a planet as inclined to the ecliptic at an angle of about 45°. But none of the planets have so great an inclination; the main object here being to illustrate the subject of nodes.

The inclination of the orbits of the several planets to the plane of the ecliptic, is shown in Fig. 2. In the centre is seen the sun. The dotted line running horizontally across the map, and through the sun's centre, represents the *plane* of the ecliptic. On the right and left are seen arcs of a circle, divided off, and numbered every ten degrees. The plain lines, inclined more or less, and passing through the centre of the sun, represent the plane of the orbits of the planets respectively. On the left, outside the graduated circle, are seen the names of the planets; and just within the circle the amount of the inclination of their orbits. This inclination is as follows:—

Mercury	7°	Ceres	$10\frac{1}{2}$°
Venus	$3\frac{1}{2}$	Pallas	$34\frac{1}{2}$
Earth		Jupiter	$1\frac{1}{4}$
Mars	2	Saturn	$2\frac{1}{2}$
Vesta	7	Herschel	$\frac{3}{4}$
Astræa	$7\frac{3}{4}$	Le Verrier	$1\frac{3}{4}$°
Juno	13		

The wide colored portion of the graduated circle shows the limits of the Zodiac, extending 8° on each side of the ecliptic.

It will be seen that the orbits of most of the planets lie within the limits of the Zodiac; but Juno, Ceres, and Pallas extend beyond its bounds. They are therefore sometimes called the *ultra zodiacal* planets. The orbit of Le Verrier is not inserted in the map.

Near the middle of Fig. 2 are seen two *comets* in their orbits; one coming down from the heights *North* of the ecliptic, passing around the sun and then reascending; and the other coming up from the depths *South* of the ecliptic. The design is to illustrate the fact that the comets do not revolve in the plane of the ecliptic, or as nearly so as do the planets; but that they approach the sun from all directions, or from every point in the heavens.

Lesson **33.**

CELESTIAL LATITUDE.

It will be understood by Lesson 25, that the *ecliptic* and *equinoctial* are two different planes, intercepting each other at an angle of 23½°. Now, although terrestrial latitude is distance north or south of the earth's equator, yet celestial latitude is not reckoned from the celestial *equator*, or *equinoctial*, but from the *ecliptic*. Celestial latitude is, therefore, *distance north or south of the ecliptic;* and as one half of the ecliptic is *south* of the earth's equator, (Lesson 25,) it follows that a star may be in *north celestial latitude*, which is, nevertheless, *south of the equinoctial.*

Lesson **34.**

CELESTIAL LONGITUDE.

(Map **6.**)

Longitude on the earth is distance east or west from any given point. On all English charts and globes it is reckoned from Greenwich Observatory, near London; but on those of American origin it is usually reckoned from the meridian of Washington City.

Longitude in the heavens is reckoned from the vernal equinox, or the first degree of Aries, eastward, around the *ecliptic* to the same point again. The map is a vertical view of the *Zodiac*, and when suspended to the south of the learner, gives a pretty correct idea of its position in the heavens.

Beginning at the first degree of the sign Aries, and passing eastward around the ecliptic, the longitude is marked off in degrees on the map, and numbered every ten degrees. The entire circle, like all other circles, consists of 360 degrees; which bring us to the point from which we started.

From what has been said, it will be obvious that if the sign Aries, for instance, were directly overhead, or on the meridian at any given time, Libra would be in the opposite part of the Zodiac, or in the heavens beyond the other side of the earth. In using longitude to describe the position of stars or other objects in the Zodiac, we should say the Twins were between the 70th and 80th degrees; the Lion between 130 and 140; the Balance between 190 and 200; the Goat between 280 and 290, &c. The student can trace them out for himself, and mark their longitude.

Lesson 35.

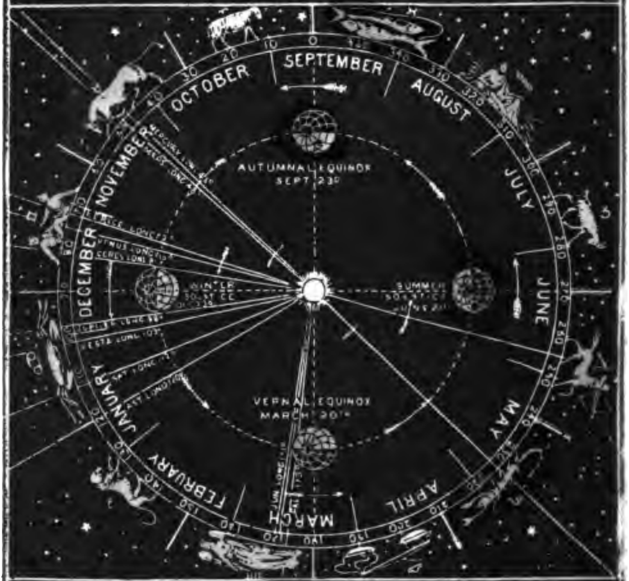
LONGITUDE OF THE ASCENDING NODES OF THE PLANETS.

(Maps **5** and **6.**)

On Map 5, Fig. 1, the line of the nodes of the interior planet enters the middle of Aries, and the middle of Libra. It was stated in Lesson 30, that the ascending node of Mercury was in the middle of Taurus, and his descending node in the middle of Scorpio. This will be fully illustrated by Map 6, where the line of his nodes is shown, and their longitude marked. The map

MAP No. 6.

ZODIAC, EQUINOXES, SOLSTICES, LONGITUDE, ASCENDING NODES, &c.



THIS MAP ILLUSTRATES

WHAT IS MEANT BY THE POLES OF THE ECLIPTIC,	P. 40
CELESTIAL LONGITUDE	P. 47
THE LONGITUDE OF THE NODES OF THE PLANETARY ORBITS.	P. 48
THE POSITION OF THE CONSTELLATIONS OF THE ZODIAC,	P. 50
THE CAUSE OF THE SUN'S APPARENT MOTION EASTWARD AROUND THE ECLIPTIC,	P. 51-52
THE DISAGREEMENT BETWEEN THE MONTHS & SIGNS,	P. 53
THE NATURE OF THE EQUINOXES, SOLSTICES & COLURES.	P. 54-56-57
THE SUBJECT OF RIGHT ASCENSION.	P. 62

represents the plane of the ecliptic, and when placed in the south side of the schoolroom, corresponds with the position of the ecliptic in the heavens. The north side, or side towards the learner, is considered as *above* the ecliptic, and the south side below it. To pass the plane of the ecliptic, therefore, from South to North, is to *ascend*; and to return from North to South is to *descend*. The arrows nearest the sun show not only the direction of Mercury, as he moves in his orbit, but also his relative distance from the sun, and the position of his nodes in the ecliptic. The entire line of Venus's nodes is also laid down on the map, together with her distance from the sun, and direction, shown by the arrows crossing the line.

In astronomical tables, the longitude of the ascending node only is given; for when this is ascertained, that of the descending node is easily inferred from it. Take for instance, the ascending node of Mercury: it is laid down on the map as in longitude 46°. Of course, then, his descending node is in the opposite side of the ecliptic, or just 180° distant. Add 180 to 46, and we have 226, the actual longitude of his descending node, as shown by the map. So by adding 180 to 75, the longitude of Venus's ascending node, we have 255, the longitude of her descending node. I have therefore given only the longitude of the ascending nodes of the planets, and one half the line of their nodes on the map; leaving the longitude of the descending nodes to be ascertained in the manner already explained.

The longitude of the ascending nodes of the planets respectively, is as follows:

Mercury	46°	Ceres	80°
Venus	75	Pallas	173
Earth		Jupiter	98
Mars	48	Saturn	112
Vesta	103	Herschel	72,
Astræa	120	Le Verrier—undetermined.	
Juno	171		

This subject should be well understood before the learner dismisses it, to enter upon the next lesson.

Lesson 36.

CONSTELLATIONS OF THE ZODIAC.

(Map 6.)

By this time the student is no doubt anxious to know the meaning of the strange-looking figures that are placed around this map, in the signs of the Zodiac. It must not be forgotten that a *sign* is merely *the twelfth part of a circle.* The largest circle on the map is divided into signs, as well as into degrees. In each sign, and outside of the circle, is placed a picture of some kind—a *bull*, a *lion*, a *lady* with wings, a *goat*, or some other figure. The reason for this we will now explain.

Outside the divided circle on the map, and around the different figures or pictures, may be seen numerous *stars.* Some are larger than others, and they seem to be scattered about at random. Such is the natural appearance of the heavens generally, in a clear night, as well that belt stretching over from west to east called the *Zodiac,* as any other portion. Now the ancients imagined that the stars were thrown together in clusters resembling different objects; and they consequently named the different groups after the objects which they supposed them to resemble. These clusters, when thus marked out by the figure of some animal, person, or thing, and named accordingly, were called *Constellations.*

As every part of the Zodiac is filled with stars, each sign has one or more of these ancient constellations. It is on this account that the figure, supposed to be represented by the constellation of each sign, is still retained; and the signs bear the names of their respective constellations.

The pupil will now more clearly discover the folly of the idea that each sign or constellation of the Zodiac "governs" a particular portion of the human body, as stated in some almanacs. How preposterous the notion that a cluster of stars, millions of miles from our globe, govern a man's head, his arms, or his feet! And yet some still think the "signs" should be consulted in reference to many important matters.

The names of the signs have already been given in Lesson 27, to which the learner may again turn, to refresh his memory, in connection with the map now before him.

Lesson 37.

THE SUN'S APPARENT MOTION IN THE ECLIPTIC.

(Maps **5** and **6.**)

In Map 5, Fig. 1, the earth is seen performing her annual journey around the sun. Now when the earth is in the sign ♎ the sun will appear to be in ♈; and as the earth moves on to ♏, the sun will appear to pass around to ♉. Hence, as the earth passes around in her orbit every year, from west to east, it is obvious that the *sun* will *appear* to make the circuit of the heavens in the same time, and in the same direction.

All the constellations of the Zodiac seem to overtake and pass by the sun westward once a year; or in other words, the sun appears to meet and pass through them all eastward, in regular order, every 365 days.

Map 6 may illustrate this subject still more clearly. The sun is seen in the centre. Around the sun the earth is seen in her orbit, the arrows showing her direction. Now when the earth is in ♉, in November, the sun must seem to be in ♏, on the opposite side of the ecliptic. So when the earth is in ♊, the sun will appear to be in ♐, &c.

On the 20th of March the *earth* is in longitude 180, or in the first degree of ♎; at which time we say the *sun* enters ♈.

The time of the sun's entrance into the different signs is as follows:—

♈, March 20th.
♉, April 20th.
♊, May 21st.
♋, June 21st.
♌, July 23d.
♍, August 23d.
♎, September 23d.
♏, October 23d.
♐, November 22d.
♑, December 21st.
♒, January 20th.
♓, February 19th.

It must not be forgotten that this motion of the sun eastward around the Zodiac, is merely apparent; and is caused altogether by the revolution of the earth around the sun. By following the earth in her orbit from March 20th, around to the same point again, the sun will seem to enter all the signs, in the order, and at the times specified in the foregoing table.

As we have our spring while the sun is passing through ♈, ♉, and ♊, these are called the *spring* signs; ♋, ♌, and ♍, are the *summer* signs; ♎, ♏, and ♐, are the *autumnal* signs; and ♑, ♒, and ♓, the *winter* signs.

This subject will be still further illustrated in the next lesson.

Lesson 38.

SUCCESSIVE APPEARANCE OF THE CONSTELLATIONS IN THE NOCTURNAL HEAVENS.

(Map 6.)

We are very apt to suppose that because we see no stars in the daytime, there are none in the heavens above us. This is an erroneous conclusion. Were it not for the light of the sun, the stars would shine out as brightly during what we now call the daytime, as they ever do in the night; but instead of seeing the same constellations that we see in the night, at any given time, we should see those only that were visible in the night *six months before;* and would be above the horizon again in the night six months afterwards.

The fixed stars surround the solar system in every direction; and the fact that we cannot see the stars beyond the sun, or in that half of the Zodiac in which he appears, (on account of his superior light,) is no proof that such stars do not exist and shine. When the sun is totally eclipsed, the stars appear in the daytime; and if we look through a long tube or descend into a deep well, so as to shut the strong light of the sun from the eye, the stars may be seen even at noon in the heat of summer.

Let this subject be illustrated by the map. Suppose a person to be observing the constellations of the Zodiac on the 21st of June. At midnight all the constellations from ♎ around to ♈ would be in sight; but at twelve o'clock the next day, when the other half of the Zodiac would be above the horizon, the sun would be between the observer and the signs ♊ and ♋, and would shed so strong a light over the whole visible heavens, as to eclipse or obscure all the stars.

But as the earth passes on in her orbit, and the sun seems to pass the signs eastward in regular order, the constellations will arise earlier and earlier every night; so that all of them will seem to pass over from east to west *in the night* in the course of a year.

This map may be used to show what constellations will be on the meridian at twelve o'clock, or at any other hour of the night, during every month in the year. In December they will be ♊ and ♋; in March ♍ and ♎; in June ♐ and ♑, &c., as the earth advances eastward in her orbit, and turns from west to east upon her axis.

Lesson 39.

DISAGREEMENT BETWEEN THE MONTHS AND SIGNS.

(Map **6.**)

The names of the months are marked around on the map from west to east, to show at what time the earth occupies any particular place in her orbit; and also when the sun enters the opposite sign. But the months and the signs do not exactly agree in longitude. The earth reaches long. 180°, and the sun enters ♈ on the 20th of March; so that there are eleven days of March left after the earth has passed into ♎, and the sun has entered ♈.

Of course, then, all the months in the year are a little more tardy, so to speak, than the signs; and are represented, in the map, as jutting by them eastward about ten degrees of longitude.

Lesson 40.

THE EQUINOXES.

(Map 6.)

The great circle of the Zodiac is divided into four parts, by imaginary lines running through the centre of the sun, and at right angles with each other. On the map they are *dotted*, to distinguish them from others, one running perpendicularly, and the other horizontally. The earth is represented as being at the points where these lines cross her orbit.

Two of these points, namely, the upper and lower, are called the *equinoctial points*. They are so called because when the earth is at either of them the sun shines perpendicularly on the equator, and consequently to each pole; and the *days and nights are of equal length* all over the world.

The plane of the equinoctial passes through the earth's equator; or, in other words, it is the equator of the earth extending off into the heavens in every direction.

The earth passes the equinoctial points on the 20th of March and the 23d of September; the first of which is called the *vernal*, and the latter the *autumnal* equinox. These points being in opposite portions of the heavens, are, of course, 180° apart, as appears by the map.

Lesson 41.

PRECESSION OF THE EQUINOXES.

The best explanation of this nice and intricate motion with which we have ever met, is from the pen of the lamented Burritt; and as we have no wish to affect originality at the expense of utility, we insert the following extract for the perusal of the student. It is taken from a chapter on the subject in the "Geography of the Heavens."

"Of all the motions which are going forward in the Solar System, there is none, which it is important to notice, more difficult to comprehend, or to explain, than the PRECESSION OF THE EQUINOXES, as it is termed.

"The equinoxes, as we have learned, are the two opposite points in the earth's orbit, where it crosses the equator. The first is in Aries; the other, in Libra. By the *precession* of the equinoxes is meant, that the intersection of the equator with the ecliptic is not always in the same point:—in other words, that the sun, in its apparent annual course, does not cross the equinoctial, spring and autumn, exactly in the same points, but every year a little *behind* those of the preceding year.

"This annual falling back of the equinoctial points, is called by astronomers, with reference to the motion of the heavens, the *Precession of the Equinoxes;* but it would better accord with fact as well as the apprehension of the learner, to call it, as it is, the *Recession* of the Equinoxes: for the equinoctial points do actually *recede* upon the ecliptic, at the rate of about 50¼″ of a degree every year. It is the name only, and not the position, of the equinoxes which remains permanent. *Wherever* the sun crosses the equinoctial in the *spring, there* is the vernal equinox and *wherever* he crosses it in the *autumn, there* is the autumnal equinox; and these points are constantly moving to the west.

"The sun revolves from one equinox to the same equinox again, in 365d. 5h. 48′ 47″.81. This constitutes the natural, or *tropical year,* because, in this period, one revolution of the seasons is exactly completed. But it is, meanwhile, to be borne in mind, that the equinox itself, during this period, has not kept its position among the stars, but has deserted its place, and *fallen back* a little to meet the sun; whereby the sun has arrived at the equinox *before* he has arrived at the same position among the stars from which he departed the year before; and consequently, must perform as *much more* than barely a *tropical* revolution, to reach that point again.

"To pass over this interval, which *completes the sun's sidereal revolution*, takes (20′ 22″.94) about 22 minutes and 23 seconds longer. By adding 22 minutes and 23 seconds to the time of a tropical revolution, we obtain 365d. 6h. 9m. 10¾s. for the length of a *sidereal revolution;* or the time in which the sun revolves from one fixed star to the same star again.

"As the sun describes the whole ecliptic, or 360°, in a tropical year, he moves over 59′ 8⅓″ of a degree every day, at a mean rate, which is equal to 50¼″ of a degree in 20 minutes and 23 seconds of time; consequently he will arrive at the same equinox or solstice when he is 50¼″ of a degree *short of the same star* or fixed point in the heavens, from which he set out the year before. So that, with respect to the fixed stars, the sun and equinoctial points fall back, as it were, 1° in 71⅔ years. This will make the stars *appear to have gone forward* 1°, with respect to the *signs* in the ecliptic, in that time: for it must be observed, that *the same signs always keep in the same points of the ecliptic, without regard to the place of the constellations.* Hence it becomes necessary to have new plates engraved for celestial globes and maps, at least once in fifty years, in order to exhibit truly the altered position of the stars. At the present rate of motion, the *recession* of the equinoxes, as it should be called, or the *precession* of the stars, amounts to 30°, or one whole sign, in 2140 years."

Lesson 42.

THE SOLSTICES.

(Map 6.)

The dotted line running *horizontally* across the map is the line of the *solstices;* and the points where this line crosses the earth's orbit are called the *solstitial points.*

At the time of the autumnal equinox, September 23d, the sun is directly over the earth's equator, and his light extends to both poles, as shown on the map. From this time to December 21st, the sun declines south, till it is perpendicular over the tropic of *Capricorn*, (so called from the sign which the sun enters on that day,) wnen its southern declination is stayed or ceases. Hence the name *solstice*.

From December 21st to March 20th the sun approaches the equinox, which it reaches at the latter period, when he begins to decline northward, till on the 21st of June he reaches the tropic of *Cancer*. He is then at the *summer solstice*. From June 21st to September 23d the sun again approaches the equator or equinox, at which time he begins again to decline south, &c.

This declination of the sun north and south, and his apparent passage through the plane of the equinoctial, twice a year, are caused by the inclination of the axis of the earth to the plane of the ecliptic, and her revolution around the sun. What we have here said will serve more fully to illustrate Lesson 25, where the obliquity of the ecliptic is considered.

Lesson 43.

THE COLURES.

(Map 6.)

The *Colures* are two great circles crossing at the *poles of the ecliptic*, (see Lesson 24,) and passing through the ecliptic at right angles. One passes through the equinoxes, and is thence called the *Equinoctial Colure;* the other passes through the solstices, and is called the *Solstitial Colure*. They are to the heavens what four meridians, each 90° apart, would be to the earth. They divide the celestial sphere into four parts, like quartering an apple. Two hoops of wire, crossing between the eye of the student and the sun, and also directly beyond the sun on the other side of the map, would represent the colures;

provided one passed through the map at the solstitial, and the other at the equinoctial points. When once the place of the colures is clearly ascertained, they are very convenient in finding particular stars or constellations either north or south of the ecliptic.

Lesson 44.

ELLIPTICITY OF THE PLANETS' ORBITS.

(Map 7.)

Thus far we have proceeded upon the supposition that the orbits of the planets were exact circles, and that consequently the several planets were always at the same distance from the sun. It is time now to state more definitely the true figure of their orbits.

Fig. 1 represents the earth as revolving in an *ellipse*, or *oval-shaped* orbit. This is its true figure; and indeed, to a great extent, the figure of all the planetary orbits. But some are more elliptical than others, and the orbits of the comets, as shown in Maps 2 and 5, are more elliptical than those of any of the planets.

Not only are the orbits of the planets elliptical, but the sun is always found one side of the centre, or nearer one end of the ellipse than the other, as shown on the map. The point where the sun is placed is called one of the *foci* of the ellipse.

Lesson 45.

PERIHELION AND APHELION.

(Map 7.)

When a planet or comet is in that part of its orbit nearest to the sun, it is said to be at its *perihelion*; and when at the point most distant, at its *aphelion*. So of the moon; *perigee* and *apogee* are the points of her orbit nearest to and most distant from the earth.

On the map the earth is seen at her perihelion on the left, and at her aphelion on the right, the two points being at very unequal distances from the sun. In stating the distances of the solar bodies, we sometimes give their *perihelion* and *aphelion*, as well as their *mean* or average distances; but in Lesson 8 the mean distances only are given. The following table will exhibit the *longitude* of their *perihelions*, respectively:

Mercury	74°	21′	46″
Venus	128	43	53
Earth	99	30	5
Mars	332	23	56
Vesta	249	33	24
Astræa	135	27	54
Juno	53	33	46
Ceres	147	7	31
Pallas	121	7	4
Jupiter	11	8	35
Saturn	89	9	30
Herschel	167	31	16
Le Verrier	299	11	00

Lesson 46.

ECCENTRICITY OF THE PLANETS' ORBITS.

(Map 7.)

The *eccentricity* of a planet's orbit is the *distance of its centre from the centre of the sun.* This will be easily understood by observing Fig. 1, where the sun is seen in the left-hand focus of the ellipse, and upon the large maps, about two inches from its centre.

These two inches would, in this case, constitute the eccentricity of the ellipse.

The eccentricity of the orbits of the different planets, is as follows:

Mercury	7,000,000	miles.
Venus	492,000	"
Earth	1,618,000	"
Mars	13,500,000	"
Vesta	21,000,000	"

Astræa	Unknown.
Juno	64,000,000 miles.
Ceres	21,000,000 “
Pallas	64,250,000 “
Jupiter	24,000,000 “
Saturn	49,000,000 “
Herschel	85,000,000 “
Le Verrier	Unknown.

From the above table it appears that the orbits of Juno and Pallas are the most elliptical, while that of Venus is almost a circle.

Lesson 47.

PHILOSOPHY OF THE SEASONS.

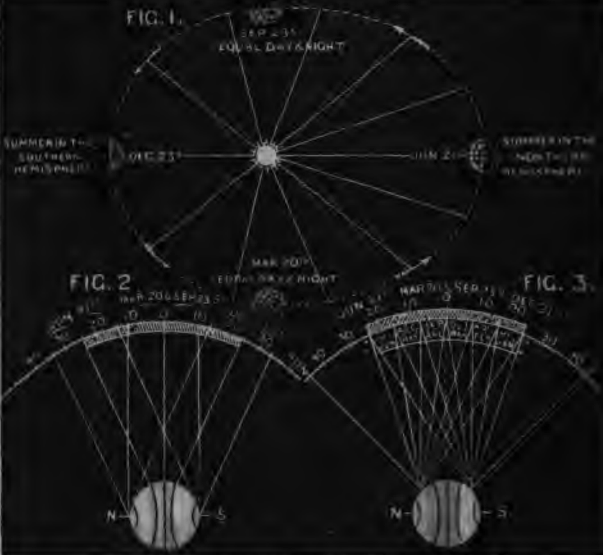
(Map 7.)

It has already been stated that the axis of the earth is inclined to the ecliptic 23° 28′. This is illustrated in Fig. 1; and also the fact that in consequence of the revolution of the earth around the sun, and the inclination of her axis to the plane of her orbit, her poles are alternately in the light six months, and in darkness six months. At the time of the equinoxes the light of the sun is seen to extend to both poles alike. On the 21st of June, the time of the summer solstice, the sun shines only to the *south* polar circle, and 23° 28′ beyond the north pole. It is then summer in the northern hemisphere. At the time of the winter solstice this order is reversed. The sun has passed from over the northern tropic, across the equinoctial, to the southern tropic; and now shines only to the north polar circle, and 23° 28′ beyond the south pole. Thus we have the regular succession of *the Seasons*.

But the map shows that we have winter in the northern hemisphere, when the earth is nearest to the sun. This may seem very strange to the learner, but it must be remembered that cold and heat in different latitudes do not depend so much upon the *distance* of the earth from the sun, as upon the manner in which the sun's rays

MAP No. 7.

THE EARTH'S ORBIT–SUN'S DECLINATION–SEASONS &C.



THIS MAP ILLUSTRATES

THE ELLIPTICITY OF THE PLANET'S ORBITS P. 58

THE PERIHELION & APHELION POINTS, PERIGEE & APOGEE P. 58

WHAT IS MEANT BY THE ECCENTRICITY OF A PLANET'S ORBIT P. 59

THE PHILOSOPHY OF THE SEASONS & WHY WE HAVE OUR WINTER WHEN THE EARTH IS NEAREST THE SUN P. 60

THE SUBJECT OF THE SUN'S DECLINATION &c. P. 61 & 2 strike her surface. Those parts of the earth upon which the rays of light fall *perpendicularly*, are always warmest; while those portions upon which his beams fall *obliquely*, are comparatively cold. It is easy to see, therefore, that when the north pole is turned *from* the sun on the 21st of December, and the rays of light fall obliquely on the northern hemisphere, it will be cold, even though the earth may be at her perihelion. But when the north pole is turned *towards* the sun, on the 21st of June, the light falls more directly upon the northern hemisphere, and we have our summer, though the earth is at her aphelion.

The only effect of the eccentricity of the earth's orbit upon her temperature is, that she has probably a greater degree of heat during summer in the southern hemisphere, when the earth is at her perihelion, than we ever have at the north in the same latitude. But this difference must be very slight, if indeed it is at all perceptible.

The subject of this lesson will be again alluded to when we come to consider the seasons of the other planets.

Lesson 48.

THE SUN'S DECLINATION.

(Map 7.)

The apparent distance of the sun north or south of the equator is called its *declination*.

From the 20th of March to the 23d of September, he has *Northern declination;* and the rest of the year *Southern declination.* His declination is nothing at the time of the equinoxes; but from that time it increases till the time of the solstices, when it amounts to 23½°. From the time of the solstices the sun gradually returns again towards the equator, and his declination constantly decreases till he passes the equinoctial, when it again begins to increase, though in another direction.

The subject of this lesson is illustrated by Figs. 2 and 3.

Fig. 2 shows the position of the sun at the time of the equinoxes and solstices; the manner in which his light strikes the earth at these times; the *zones* of the earth; the extent of the sun's declination, &c.

Fig. 3 is still more full and explicit. In addition to what is contained in Fig. 2, it shows the place or declination of the sun for every month in the year, and the manner in which his beams strike the middle of both the temperate zones during every successive month. Take, for instance, the north temperate zone, at the 45th degree of latitude. On the 21st of December, when the sun has the greatest southern declination, and, as shown in Fig. 2, shines vertically on the tropic of Capricorn, he would seem to be quite low down in the south, even at noon; and his rays would strike the north temperate zone quite obliquely, as shown in the figures. From December 21st to June 21st the sun advances towards the north, and the obliquity of his rays constantly diminishes. On the 21st of June the light falls quite obliquely on the southern hemisphere, where it is then winter. The two lines running off from the earth's surface to the letter Z, are designed to show the perpendicular and *zenith* of the 45th degree of latitude; and also how much the sun lacks of being directly overhead at these points, at the time of the solstices.

It will be easy to see from these figures that *declination is to the heavens what latitude is to the earth.* They may be used, also, to show the use of a quadrant, and the manner of determining latitude by the sun's meridian altitude, and his declination.

Lesson 49.

RIGHT ASCENSION.

(Map 6.)

Right Ascension is distance east of the vernal equinox, measured on the *equinoctial.*

In Lessons 33 and 34, it was shown that celestial latitude and longitude answered to terrestrial, except that in the former case we reckoned *from* and *on* the *ecliptic*, instead of the *equinoctial.*

On the other hand, declination and right ascension refer directly to the equinoctial; and consequently answer to longitude and latitude on the earth.

The learner may here start the inquiry, Why were not declination and right ascension called celestial latitude and longitude, seeing that they refer to the celestial equator, instead of measurements from and on the *ecliptic?* Such a question is not easily answered. This interchange of terms, as it may be called, is rather unfavorable to a ready and clear understanding of these topics. Even at this late period it might be a service to the science in the end, to call declination celestial latitude, and right ascension celestial longitude.

Right ascension is reckoned around on the equinoctial to 360°, answering to 360° of celestial longitude, only that one is reckoned on the *equinoctial,* and the other on the *ecliptic.*

Lesson 50.

INCLINATION OF THE AXES OF THE PLANETS TO THE PLANE OF THEIR RESPECTIVE ORBITS.

(Map 8.)

That the pupil may fully understand this lesson, it may be well to recapitulate some things already learned.

1st. The *Ecliptic* is described Lesson 23.

2d. The *Orbits* of the planets are described Lessons 4, 43, and 45.

3d. The inclination of the *orbits* to the plane of the *ecliptic* is the subject of Lesson 32.

We now call attention to the inclination of the *axes* of the several planets to the plane of their *orbits.*

This is a lesson of great interest and importance; and although so far as the earth is concerned it has already been anticipated, in our remarks on the seasons, declination, &c., still it opens a rich field of inquiry before the student, and should receive a good degree of attention.

On the map the dotted horizontal lines represent portions of the orbits of the planets, with the exception of the sun, in which case they represent the plane of the *ecliptic.* The *axis* of each planet is seen inclined to the plane of its *orbit* at its true angle. The *equators* are shown by the double lines crossing the axes at right angles. The *zones* are distinguished by curved boundary lines, and by the different colors—the torrid zones being *red,* the temperate *green,* and the frigid *white.*

It will readily be seen that the extent of the torrid zone of a planet depends altogether upon the amount of its polar inclination. If its axis be much inclined, as in the case of Venus, it will have a wide torrid zone; but if its axis is but little inclined, like that of Jupiter, it will have a narrow torrid zone.

The sun's declination north and south of the equator of each planet must be just equal to its polar inclination; and as its torrid zone includes both its northern and southern declination, it follows that it must be twice as wide as the amount of its polar inclination.

These principles will be more clearly seen by the following table, in which the polar inclination, greatest declination, and width of torrid zone, are compared:

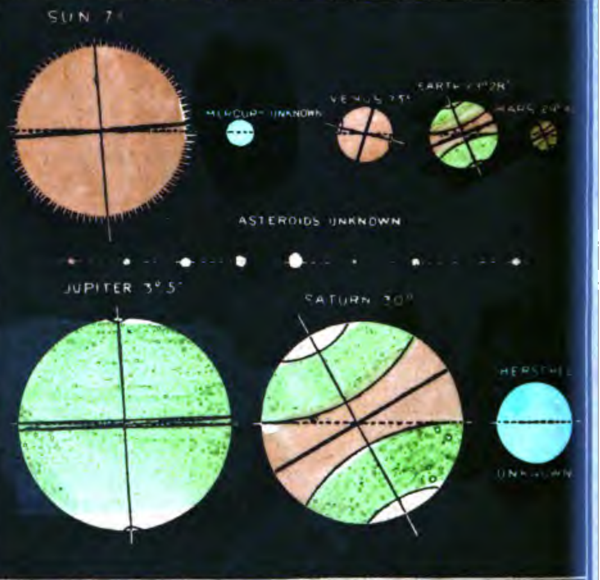
	Inc. of axis.		Declination.		Torrid zone.	
Venus . . .	75°	00′	75°	00′	150°	00′
Earth . . .	23	28	23	28	46	56
Mars . . .	28	40	28	40	57	20
Jupiter . . .	3	5	3	5	6	10
Saturn . . .	30	00	30	00	60	00
The Sun . .	7	20				

Only the first part of this table need be committed to memory; but the whole should be studied and compared with the map until its *principles* are fully understood.

Of Mercury, the Asteroids, Herschel, and Le Verrier, nothing definite is known respecting their polar inclination; consequently we have no knowledge of the extent of their zones, or the character of their seasons.

MAP No. 8.

INCLINATION OF POLES TO ORBITS-SEASONS OF THE PLANETS



THIS MAP ILLUSTRATES

THE OBLIQUITY OF THE ECLIPTIC	P 48
THE INCLINATION OF THE AXES OF THE PLANETS TO THE PLANE OF THEIR RESPECTIVE ORBITS	P 63
THE CAUSE OF THE SEASONS. ZONES &c	P 65
THE SEASONS OF VENUS.	P 65
THE SEASONS OF MARS	P 66
THE SEASONS OF JUPITER & SATURN	P 67

Lesson 51.

SEASONS OF THE DIFFERENT PLANETS.

(Map 8.)

The general philosophy of the seasons, together with the seasons of the earth, are already explained in Lesson 46. The same subject will now be resumed, as it relates to the rest of the planets.

The seasons of the planets depend upon two causes: the inclination of their axes to their respective orbits, and their periodic revolutions around the sun. The former determines the *extent* of their *zones*, and the latter the *length* of their *seasons*.

The effects of polar inclination are seen in the contrast presented by Venus and Jupiter. Venus, with a polar inclination of 75°, has a torrid zone 150° wide; while Jupiter, whose axis is inclined but 3° 5′, has a torrid zone only 6° 10′ wide. After the statement of these general principles, we shall proceed briefly to notice the seasons of the several planets.

It might be well, however, for the student to turn back to Lesson 46, and review it in connection with this map. Especially let him examine the figure of the earth and her zones with a view to the *obliquity of the ecliptic*, explained in Lesson 25. Call to mind also the subject of the sun's declination, Lesson 47, and the difference between referring to the *ecliptic*, as in celestial latitude and longitude, and to the *equinoctial*, as in right ascension and declination. See Lessons 33, 34, 47, and 48.

Lesson 52.

SEASONS OF VENUS.

(Map 8.)

The tropics of Venus are 75° from her equator, and within 15° of her poles. She has no frigid zone, or polar circles. Her periodic time being only 225 days, (Lesson 18,) the sun passes in that short time from her northern solstice through her equinox to her southern solstice, and back to the point from which he started. So great is the sun's declination on Venus, that when he is over one of her tropics, it is winter not only at the other tropic, but also at her equator; and as the sun passes over from tropic to tropic, and back again every 225 days, making spring at the equator as he approaches it, summer as he passes over it, autumn as he declines from it, and winter when he reaches the tropic; it follows that at her equator Venus has *eight seasons* in one of her years; or in 225 of our days. Her seasons, therefore, at her equator, consist of only about four weeks of our time, or 28⅛ days; and from the heat of summer to the cold of winter can be only about 56 days. At her tropics she has only four seasons of 56 days each.

At first view it might appear to the reader that such an arrangement must be fatal to all vegetable life, especially at Venus's equator; but it should be remembered that He who inclined the axis of Venus to her orbit, and prescribed her periodic time, could as easily clothe her with vegetation of a month's growth, as with that requiring the lifetime of the oak or the cypress to bring it to perfection.

Lesson 53.

SEASONS OF MARS.

(Map 8.)

The polar inclination and zones of Mars are very similar to those of the earth; but owing to the difference of his periodic time, his seasons are very different from ours. His year of 687 days is divided into four seasons of about 172 days each, or nearly twice the length of the seasons of the earth.

His polar inclination is 5° 12′ greater than that of the earth; making his torrid zone wider, and his polar circles greater than ours; while his temperate zones are somewhat narrower.

Lesson 54.

SEASONS OF JUPITER.

(Map 8.)

So slight is the inclination of Jupiter's axis to his orbit, that it affords him but a very narrow torrid zone. The inclination of his orbit to the ecliptic is but 1° 15′, and his axis is inclined to his orbit but 3° 5′; so that his axis is nearly perpendicular to the ecliptic. The sun never departs more than 3° 5′ from his equator, and still, as his periodic time is about 12 years, (Lesson 18,) he has alternately six years of northern and six of southern declination. His narrow torrid zone and small polar circles leave very extensive temperate zones. In passing from his equator to his poles, we meet every variety of climate, from the warmest to the coldest, with but slight variations in any latitude, from age to age. His days and nights are always nearly of the same length, as the sun is always near his equinoctial. His poles have, alternately, six years day and six years night.

In connection with the above facts, it may be well to associate the amount of *light* received by this planet; his *magnitude;* his *oblate figure;* his *rapid rotation* upon his axis; and his *distance* from the sun. The student cannot too often call up the facts already learned, as he advances from lesson to lesson. In this way he will soon be able to state the most interesting particulars respecting each of the solar bodies.

Lesson 55.

SEASONS OF SATURN.

(Map 8.)

The polar inclination and zones of Saturn differ but little from those of Mars; but his seasons are greatly modified by the length of his periodic time. This being about 30 years, his four seasons must each be about 7½ years long; and his polar regions must have, alternately, 15 years day, and 15 years night.

The Rings of Saturn which lie in the plane of his equator, and revolve every 10¼ hours, are crossed by the sun when he crosses the equinoctial of the planet. During the southern declination of the sun, which lasts fifteen years, the south side of the rings is enlightened, and has its summer. It has also its day and night, by revolving in a portion of the planet's shadow.

When the sun is at the southern tropic, it is midsummer on the south side of the rings; as the rays of light then fall most directly upon them. As the sun approaches the equator, the temperature decreases, till he crosses the equinoctial, and the long winter of fifteen years begins. At the same time the north side of the rings begins to have its spring; summer ensues, and in turn it has fifteen years of light and heat.

The Rings of Saturn will be turned directly towards the earth, about the middle of September, 1849; at which time the light of the sun will extend to both poles of the planet. Of course Saturn is then at one of his *equinoxes*. Seven and a half years after, he will reach one of his *solstices*—his rings, as seen, will appear fully expanded from the earth,—the sun will have his greatest possible declination from Saturn's equinoctial, and it will be winter at one of his poles, and summer at the other. In seven and a half years longer, he will reach his other equinoctial point, and his rings will be invisible again. Saturn's Rings will be invisible from the 22d of April, 1848, until January 19th, 1849; excepting that they may be seen from the 3d to the 12th of September, 1848.

Of the seasons of Saturn, and the structure, dimensions, and uses of his wonderful rings, we shall remark further hereafter in a distinct lesson, in connection with Map 11.

From Map 8 and the foregoing remarks, it must be obvious to the learner that cold and heat, winter and summer, "seed-time and harvest," are not peculiar to our globe, but are characteristic of every world with which we are to any considerable extent acquainted.

MAP No. 9.

CONJUNCTIONS, OPPOSITION, TRANSITS, PHASES OF VENUS, &c.

FIG. 1

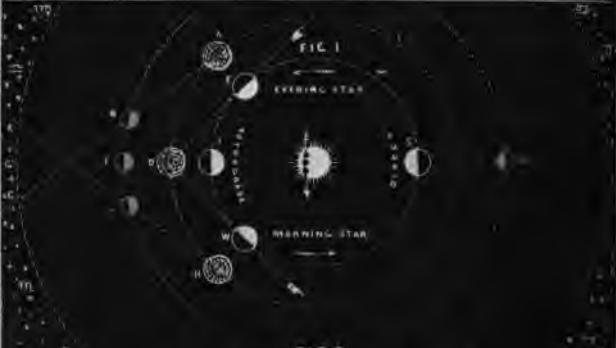
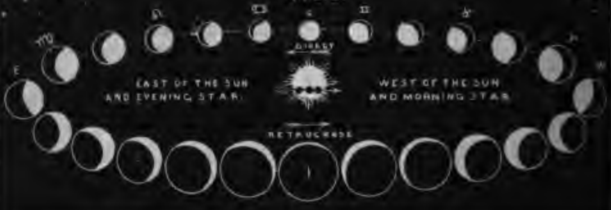


FIG. 2.


DIRECT
E
EAST OF THE SUN AND EVENING STAR.
WEST OF THE SUN AND MORNING STAR
W
RETROGRADE

THIS MAP ILLUSTRATES

THE SUBJECT OF CONJUNCTIONS & OPPOSITIONS OF PLANETS P. 69

THE DIFFERENCE BETWEEN A SIDEREAL AND A SYNODIC REVOLUTION. _ _ _ _ _ _ _ _ _ _ _ _ _ _ P. 70. 71

WHAT IS MEANT BY THE GREATEST ELONGATION OF A PLANET EAST OR WEST. _ _ _ _ _ _ _ _ _ _ _ _ _ P. 72

WHAT IS MEANT BY A PLANETS BEING STATIONARY. _ _ P. 72

THE SUBJECT OF DIRECT & RETROGRADE MOTIONS _ _ P. 73

THE CAUSE OF THE RETROGRADE MOTIONS OF THE EXTERIOR PLANETS _ _ _ _ _ _ _ _ _ _ _ _ _ P. 74

HOW VENUS IS, ALTERNATELY, MORNING & EVENING STAR _ P. 75

THE CAUSE OF THE TELESCOPIC PHASES OF MERCURY & VENUS. P. 76

Lesson 56.

CONJUNCTIONS AND OPPOSITION OF PLANETS.

(Map 9.)

When any two or more of the solar bodies are found *in the same longitude*, they are said to be in *conjunction*. Fig. 1 represents the Sun in the centre, and Venus, the Earth, and Mars, at different points in their orbits. If the Earth was at D, and Venus at I or S, she would be in conjunction with the Sun, both appearing to be at a point between ♉ and ♊, or according to Map 6, in the 60th degree of longitude.

The *interior* planets have two conjunctions; the *inferior conjunction*, when between the earth and the sun, as at I; and the *superior conjunction*, when beyond the sun, as at S. At the superior conjunction the enlightened side of the planet is towards the earth; and at her inferior, the dark side.

When at her superior conjunction, Venus is 154 millions of miles from the earth, but when at her inferior conjunction, she is only 26 millions of miles distant. The reason for this great difference will be seen by a glance at the map; which shows her the whole diameter of her orbit farther off when at S than at I.

The *exterior* planets have a *superior* conjunction, as Mars at N; but they can never get between the earth and the sun to form an *inferior* conjunction. When, therefore, a planet gets in the same longitude as the earth, like Mars at F, it is said to be in *opposition*.

A planet in conjunction rises and sets nearly with the sun; but one in opposition rises when he sets, and sets when he rises.

The position of planets with respect to each other is sometimes represented by an astronomical sign. Thus ☌ denotes *conjunction*, and ☍ *opposition*.

Lesson 32 shows the orbit of Venus to be inclined to that of the earth at an angle of 3½°; hence as one half of her orbit is above the ecliptic, and the other half below, she will always appear either above or below the sun when in conjunction, except when she is at one of her nodes; in which case she will appear to pass over the sun's disc, as represented in the figure. See Lesson 31.

Lesson 57.

SIDEREAL AND SYNODIC REVOLUTIONS.

(Map 9.)

The *sidereal* or *periodic revolution* of a planet is its passage from any particular point in its orbit, around to the same point again.

A *synodic revolution* is one extending from either an inferior or superior conjunction to the same conjunction again. It is therefore considerably more than one complete revolution around the sun.

For example: were the earth stationary at D, the superior conjunction of Venus would happen 112½ days after her inferior conjunction; or in just half her periodic time; but as both are in motion in the same direction, one revolving in 365 days, and the other in 225, it is obvious that when Venus reaches the point I, the earth will be far behind; and when the earth reaches D, Venus will have advanced to M in her second round; and will then have to overtake the earth before an inferior conjunction can be effected. This will occur when the earth reaches the point L in her second round.

From one inferior conjunction to another is 594 days; requiring about 2⅔ revolutions of Venus, and nearly 1⅔ revolutions of the earth.

The periodic times of the planets were given in Lesson 18; but for the sake of a better understanding of the subject, the sidereal and synodic periods will here be given in connection. They are as follows:

	Sidereal.	Synodic.
Mercury - - -	88 days. -	115 days.
Venus - - -	225 " -	594 "
Earth - - -	365 " -	365 "

	Sidereal.		Synodic.
Mars	1 year—	322 days.	780 days.
Vesta	3 “	230 “	503 “
Astræa	4 “	105 “	476 “
Juno	4 “	131 “	474 “
Ceres	4 “	222 “	466 “
Pallas	4 “	222 “	466 “
Jupiter	11 “	317 “	399 “
Saturn	29 “	175 “	378 “
Herschel	84 “	—— “	369½ “
Le Verrier	217 “	119 “	366¾ “

This is an interesting table, and may be studied for some time by the more advanced student to great advantage. He may imagine Mercury hurrying round to his starting-point in 88 days, and in 27 more overtaking the earth, even before she has performed one-third of her annual journey.

The periodic time of Mars being nearly double that of the earth, his synodic period is but little over two years. By subtracting the earth's period from the synodic period of the rest of the planets, the remainder will show how long the earth is in overtaking the exterior planets respectively, after she has completed one revolution. Thus, the synodic time of Vesta is 503 days. In 365 days the earth completes one revolution, and reaches the point from which she set out. Vesta is then 365 days *ahead* of the earth, but moving at a four years' pace; so that in 138 days the earth overtakes her, and they are again in conjunction. In the case of Jupiter, Saturn, &c., it requires still less time. Their periods are long, and they move slowly in longitude; so that when the earth has completed a period, they are but a short distance in advance, or to the east of her, and she soon overtakes them. By subtracting, it will be seen that the time required is, for Jupiter, 34 days; for Saturn, 13 days; for Herschel, 4½ days; and for Le Verrier only 1¾ days. Map 2 might be serviceable in illustrating this subject, so far as relates to the exterior planets.

The learner must not forget that the exterior planets have but one conjunction, while the interior have two;

and that in the preceding table the time is given from one conjunction to another *of the same kind.* The opposite conjunction occurs in just half the synodic period.

Lesson 58.

ELONGATIONS OF A PLANET.

(Map 9.)

The elongation of an interior planet is its angular distance east or west of the sun, according as it follows or precedes him. The greatest elongation of Venus is 48°, and that of Mercury only 29°.

But these alternate elongations east and west are not always the same. Those of Mercury vary from 16° 12′ to 28° 48′; while those of Venus vary much less. E and W, on the map, mark the positions of Venus at the time of her greatest elongation.

From the above facts several other important conclusions are deduced. The first is, that the orbits of Mercury and Venus are *within* that of the earth. If it were not so, they would depart farther from the sun, and sometimes appear in *opposition* to that luminary. In the second place, they show that the orbit of Mercury is within that of Venus; otherwise his elongation would equal or exceed that of Venus. Thirdly, they show the ellipticity of the orbits of Mercury and Venus. If their orbits were complete circles, their greatest elongation would always be the same; but as it varies, it proves that they are not always at the same actual distance from the sun, or, in other words, that their orbits are more or less elliptical.

Lesson 59.

WHEN PLANETS ARE SAID TO BE STATIONARY.

(Map 9.)

For a short time, while at or near their greatest elongation, the interior planets seem neither to recede from, nor approach towards, the sun. They are then said to be *stationary*. These periods are just before and just after an inferior conjunction. They are represented in Fig. 1 at E and W. At E the planet would be coming *towards* the earth, and at W *going from it*.

Lesson 60.

DIRECT AND RETROGRADE MOTIONS.

(Map 9.)

It was stated in Lesson 18, that the planets revolved in their orbits from west to east, or in the order of the signs. But they do not always *appear* to maintain this order. At times they advance regularly through the signs, and again retrace their course. Hence the distinction of *direct* and *retrograde* motions. Direct motion is from west to east; retrograde is from east to west.

The general course of the planets is eastward, their retrogression being but for a short time, when the direct course is again resumed.

The cause of this seeming irregularity will appear by again consulting Fig. 1. The signs will be seen marked ♈, ♉, ♊, &c., on the right and left sides of the map, and may be imagined around the whole figure. When Venus is at W, she would seem, to an observer on the earth, to in ♓, in the signs of the upper figure. As she passed in the direction of the arrows, from W to E, her motion ould be direct, and she would seem to pass through ’, ♉, ♊, ♋, and into ♌; but in passing from E to W he would seem to fall back through ♋, ♊, &c. These re her direct and retrograde motions.

But the amount of apparent retrogression is greatly reduced by the motion of the earth in the same direction; as for instance, if the earth advances only from D to the lower hand (☞) during a revolution of Venus, she would not retrograde beyond the beginning of ♋.

The above principles are as applicable to Mercury as to Venus.

Lesson 61.

RETROGRADE MOTIONS OF THE EXTERIOR PLANETS.

(Map 9.)

The apparent retrogression of the exterior planets is effected in a manner somewhat different from that of the interior planets.

Suppose the earth at A, and Mars at B; he would be seen among the stars at C. As the earth gains upon Mars, and reaches the point D, Mars, being at F, would be seen at G, or west of where he was first seen. When the earth reaches H, and Mars is only at J, he will be seen at K; or some 15° back, or west, of his first apparent position.

The part of the great circle of the heavens through which a planet seems to retrograde, is called its *arc of retrogradation*. In the figure it is the arc of the circle between C and K.

The following table will show the arc of retrograde motion, and also the time of retrogression in days:—

	Arc.	Days.
Mercury - - -	13½°	23
Venus - - -	16	42
Earth - - -		
Mars - - -	16	73
Vesta - - -	13	83
Astræa - - -	12	99
Juno - - -	12	99
Ceres - - -	12	99
Pallas - - -	12	99
Jupiter - - -	10	121
Saturn - - -	6	139
Herschel - - -	4	151
Le Verrier - -	1	180

Here it may be interesting to observe, that the more distant the exterior planet the less its *arc* of retrogradation, and the longer its *time*. The reason for this may be illustrated by the map, Fig. 1. Suppose Mars at F to represent Herschel. Now as his year consists of eighty-four of our years, it follows that the earth would pass him eighty-three times during one of his revolutions; and that during a revolution of the earth he would pass through only $\frac{1}{84}$th part of his orbit; or about 8¼°. The planet *F* would thence seem to retrograde slowly on the ecliptic nearly half the year; or while the earth was passing from A to H on the map.

For the same reasons the arc would be still less, and the time of retrogression still longer in the case of Le Verrier. The more distant the planet is from the earth's orbit, the smaller the angle which will be necessary to include that orbit; and the less the arc of retrogradation described by the planet on the concave of the heavens.

Lesson 62.

VENUS AS MORNING AND EVENING STAR.

(Map 9.)

> "Next Mercury, Venus runs her larger round,
> With softer beams and milder glory crown'd;
> Friend to mankind, she glitters from afar,
> Now the bright *evening*, now the *morning* star.
> From realms remote she darts her pleasing ray,
> Now leading on, now closing up the day;
> Term'd *Phosphor* when her *morning* beams she yields,
> And *Hesp'rus* when her ray the *evening* gilds."

It has been seen that in making her revolutions, Venus is sometimes East and sometimes West of the sun. From her inferior to her superior conjunction she is *west* of the sun; and from her superior to her inferior conjunction *east* of him. Now it is obvious that when she is west of the sun she will go down before him, and cannot be seen in the west after sunset; but if she sets before the sun she will rise before him, and can be seen in the east before sunrise. When, therefore, Venus is west of the sun she is *morning star*. When she is east of the sun she rises after the sun, and may be seen above the horizon in the west, after the sun is set. She is then *evening star*. The ancients supposed these were two different stars, calling the first *Phosphor*, and the other *Hesperus*. Venus is alternately one or the other about 292 days. For 146 days after her superior conjunction she lingers farther and farther behind the sun, in the west, till she reaches her greatest *eastern* elongation. She then seems to approach the sun again for 146 days, when she passes her inferior conjunction, and becomes morning star. After this she rises more and more in advance of the sun for 146 days, when, having reached her greatest *western* elongation, she begins to fall back again towards the sun, and in 146 days is at her superior conjunction. This passed, she is again evening star.

Fig. 2 is designed fully to illustrate all that may yet seem obscure to the learner. From W to E will represent her *direct* motion, in the order of the signs. From E around to W again shows her *retrograde* motion. S and I mark her superior and inferior conjunctions; and the appearance of a *transit* is represented on the sun's disc.

By imagining the sun and Venus as represented in the figure, to rise in the east and pass over to the west, the student will see that if Venus were at W she would be morning star, and at her greatest elongation; but if at E she would be evening star, &c. It would be a useful exercise to observe the exact position of Venus in the heavens, at the time of studying these lessons, and then point out that position on the map.

Lesson 63.

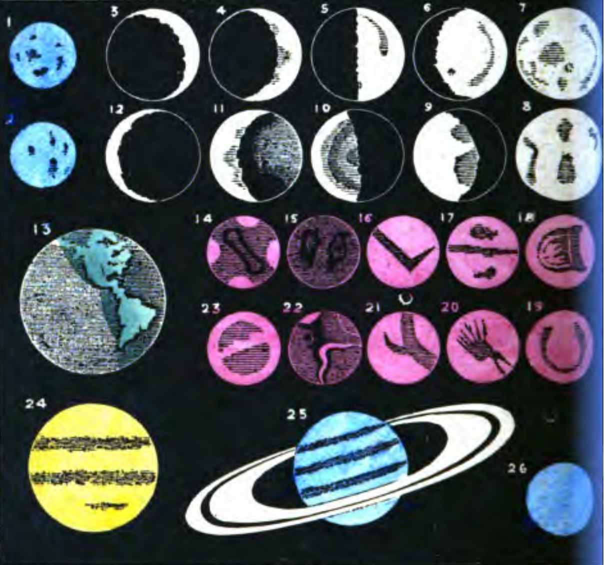
PHASES OF MERCURY AND VENUS.

(Map 9.)

As Mercury and Venus are opaque bodies, like our earth, only those portions of their surface appearing bright which are enlightened by the sun; and as their enlightened sides are turned towards us, little by little, they present, when seen through a telescope, all the different appearances or phases of the moon.

MAP No. 10.

TELESCOPIC VIEWS OF THE PRIMARY PLANETS.



THIS MAP ILLUSTRATES

THE GENERAL RESEMBLANCE OF THE PLANETARY BODIES. P. 77.
THE TELESCOPIC APPEARANCES OF MERCURY & VENUS. _ P. 78.
THE APPEARANCE OF THE EARTH, AS A PLANET, WHEN SEEN FROM A DISTANCE. _ _ _ _ _ _ _ P. 79.
THE TELESCOPIC APPEARANCE OF MARS, THE ASTEROIDS, & JUPITER. _ _ _ _ _ _ P. 80. 82.
THE TELESCOPIC APPEARANCE OF SATURN & HIS RINGS. _ _ _ _ _ _ _ _ _ _ _ 82.

Fig. 2 represents Venus in her orbit, and exhibiting her different phases, in the course of her revolution. At I, her inferior conjunction, her dark side is towards us; and her enlightened side invisible. As she passes from I to W, and so on round to S, we see more and more of her enlightened side, till her whole illuminated disc is in view. From her superior to her inferior conjunction she continues to wane, till her dark side is again turned directly towards the earth.

Although when at S, her whole enlightened hemisphere is towards the earth, still she is less brilliant than when at E and W; owing to her increased distance from us, and her being, apparently, in the neighborhood of the sun.

It will be seen that Venus is the whole diameter of her orbit nearer to us, at her inferior conjunction, than at her superior; and as her mean distance from the sun is 69 millions of miles, her distance from the earth must vary to the extent of twice that amount, or the whole diameter of her orbit, which is 138 millions of miles. It is not strange, therefore, that her apparent magnitude undergoes sensible variations between her conjunctions.

Lesson 64.

TELESCOPIC VIEWS OF THE PLANETS.

(Map 10.)

Although in the preceding lessons we have frequently alluded to the appearance of some of the planets, when seen through a telescope, it is thought important to describe those appearances more in detail; and to illustrate the descriptions by appropriate engravings. This is the object of Map 10.

Before any particular planet is noticed, it may be well to state a few general facts respecting these primary bodies.

1. They all have the same general *figure*, namely, that of spheres or spheroids.

2. They all seem to be surrounded by an *atmosphere*, of greater or less density and extent.

3. The spots or belts seen upon their surfaces from time to time, by different observers, seem to be in the main permanent, and indicative of large divisions of land and water, like our continents and seas.

With these preliminaries, they will now be taken up and considered in order.

MERCURY.

"Of MERCURY," says Dr. Herschel, "we can see little more than that it is round, and exhibits phases. It is too small, and too much lost in the neighborhood of the sun, to allow us to make out more of its character." But this is not the opinion of every observer. Mr. Schroeter, an eminent German astronomer, assures us that he has not only seen *spots* on the surface of Mercury, but also *mountains*, the height of two of which he actually measured. They were situated in the southern hemisphere of the planet, and the highest was found to be nearly eleven miles in height.

Numbers 1 and 2 on the map, are representations of Mercury. The spots supposed to have been seen by Schroeter, are represented on his disc, and he has a faint bluish tint as when seen through a telescope. As elsewhere stated, he exhibits the different phases of the moon during his synodic journey around the sun.

VENUS.

The figures from 3 to 12 inclusive, are telescopic views of *Venus*. As a whole they represent her various *phases*, as already explained in Lesson 63; and illustrated by the lower figures of Map 9. Figures 3, 4, 11, and 12, show her horned, as when near her inferior conjunction. Figures 5 and 10 show her as she appears when at her greatest elongation; 6 and 9 as *gibbous*, between her greatest elongation and superior conjunction; and 7 and 8 as she appears at her superior conjunction.

These ten views present a great variety, as it respects the *spots* that appear upon the surface of the planet. They seem not only to vary in *form*, but also in their *number*. It may be proper, therefore, to state that these views were not all had by the same person, nor during the same period of time.

Fig. 3 is a view by *Schroeter*, in 1791.
Fig. 4 " *Bianchini*, in 1726.
Fig. 5 " *Cassini*, in 1667.
Fig. 6 " " in 1666.

Figures 7 and 8 represent the face of the planet, as it is supposed she would have appeared, at the time of some of the other views, had her whole hemisphere been enlightened. It will be seen that each of these figures combine two other views.

Fig. 9 is a view by Schroeter, in 1790.

Fig. 10 is a view often had by the celebrated Dr. Dick.

Figures 11 and 12 are repetitions of former views, with the crescent inverted, in order to illustrate the subject of Venus's phases.

The *surface* of Venus is variegated with *mountains*, some of which are estimated to be over twenty miles in height. Three elevations have been estimated at 10¾, 11¼, and 19 miles, respectively.

The *atmosphere* of Venus is supposed to surround her to the depth of only about three miles; but it is supposed to be very *dense*.

The *color* of Venus is a *silvery white*. When at her greatest elongation, she is sufficiently bright to cause a perceptible shadow if her light is intercepted.

THE EARTH.

That the learner may know the grounds of the inferences drawn from the telescopic appearances of the planets, in regard to their geography, or their great natural divisions, as continents, seas, &c., we present him at No. 13 with a *telescopic view of the Earth*. Let him imagine himself placed upon *Mercury*, for instance, with a good telescope, observing our planet. At the time of her opposition she would appear *full* from Mercury. The continents and islands would appear *brighter* than the rest of her disc; as they would reflect a stronger light than oceans, seas, and lakes. By watching these spots they would be found to cross the earth's disc in 12 hours, from which the observer would infer that our globe revolved on her axis in 24 hours; and from the *direction* of the spots he would deduce the *inclination* of her axis to the plane of her orbit.

From the passage of *clouds* over her surface, and other phenomena, it would be inferred that the earth had an *atmosphere*, and the different zones, and the changes of the seasons, might present a variety of *colors* to the celestial observer.

To a person on one of the *exterior* planets, the earth would present all the phases of the moon.

The study of geography has no doubt made the learner familiar with the figures of the continents, islands, &c., upon the earth's surface; but if he can divest himself for a moment of all particular knowledge of our globe, and contemplate her from a distance, as a *planet*, with what new and surprising interest does it invest her! She not only becomes one of a class, from which we may reason analogically respecting the physical constitutions and design of other worlds; but while we look with wonder upon the planetary orbs, and long to know more of their physical structure, we look upon the earth as the only orb which *we* are allowed to visit, and with whose history and peculiarities *we* may now become acquainted. And as the student surveys the whole Western hemisphere, let him inquire, "What is *man!*" What is a *city*, an *empire*, or a *world*, in the great universe of the Almighty?

MARS.

The figures from 14 to 23 inclusive are representations of *Mars*. The first two, namely 14 and 15, are views by Cassini, as long ago as 1610. They are copied from a volume of the Transactions of the Royal Society of London. Figures 16 and 17 represent views had by Maraldi, a celebrated French astronomer, in 1704. Figures 18 and 19 represent the appearance of the spots on Mars, as seen by Dr. Hook in 1666, from a drawing made at the time by him. Figures 20 and 21 represent views by Sir William Herschel, previous to 1784. Fig. 22 is a view by Sir John Herschel, as copied by Nichol in his "Solar System," and by several other astronomical writers. Fig. 23 is a view by Dr. Dick, in 1832, and also in 1837. It is copied, as several of the above are, from his "Celestial Scenery."

It may seem impossible to the learner that all this variety in appearance could be produced by permanent objects on the surface of the planets; but let him remember that the map of Mars, which he is studying, is drawn upon a *sphere*; and that the revolutions of a planet would necessarily produce a constant change, not only in the general appearance, but also in the apparent form of the spots.

The bright spot on the upper end of Fig. 22, at the planet's north pole, is supposed to be the reflection of light from *snow* and *ice*. This supposition is rendered probable by the fact that the spot disappears as the north pole of the planet is turned towards the sun, and returns again with the departure of the direct rays of the sun, and the return of winter.

The *surface* of Mars is variegated with oceans, seas, and continents, with mountains and vales, like all the rest of the planetary bodies. "On this planet," says Dr. Herschel, "we discern, with perfect distinctness, the outlines of what may be continents and seas." The celebrated Mädler, of Berlin, constructed a complete map of the surface of Mars, with accurate delineations of its great natural divisions, as one would draw an outline map of the world from an artificial globe.

The *color* of Mars is *red*, owing, it is supposed, to the density of his atmosphere, which may color the whole scene, as clouds put on a gorgeous crimson in the morning or evening sky. This color is not merely telescopic: it is the natural color of the planet as seen by the naked eye; and by it he may easily be distinguished from the fixed stars.

THE ASTEROIDS.

Of the *Asteroids* very little is known, on account of their distance and their diminutive size. A thin haze, or nebulous envelope, has been observed around Pallas, supposed to indicate an extensive atmosphere; but no spots or other phenomena have ever been detected. It is hoped that if ever Lord Rosse returns from examining the distant nebulæ, he will give us some new light respecting the bodies of the Solar System.

The Asteroids are never visible to the naked eye. Through a telescope they have a pale ash color, with the exception of Ceres, which in color resembles Mars.

JUPITER.

Fig. 24 is a representation of *Jupiter*,—the prince of planets. His natural color is a palish *yellow*. His *belts* are seen where they are usually found, namely, on each side of his equator, or in his temperate zones. The map shows his *oblate form*, or the difference between his polar and equatorial diameter.

What the belts of Jupiter are is uncertain. "They are generally supposed to be nothing more than *atmospherical phenomena*, resulting from, or combined with, the rapid motion of the planet upon its axis." In *number* they vary from one to eight. Sometimes they continue without change for months, and at other times break up and change their forms in a few hours. Dark spots are also frequently seen in these belts, one of which was known to maintain the same position for upwards of forty years.

Lesson 65.

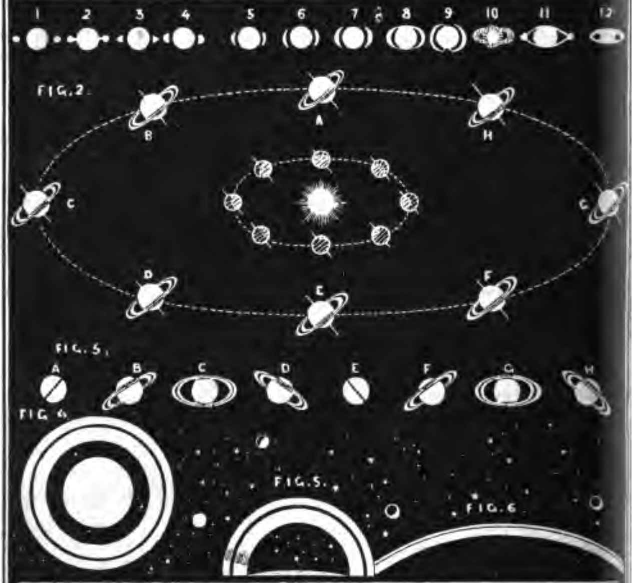
TELESCOPIC VIEWS OF SATURN.

(Maps **10** and **11**.)

Fig. 25, Map 10, is a telescopic view of Saturn with his *belts* and *rings*. The *belts* resemble those of Jupiter, already described. His *rings* will be noticed in connection with Map 11, to which the student is referred. The

MAP No. 11.

SATURN IN HIS ORBIT, PHASES, TELESCOPIC VIEWS, &c.



THIS MAP ILLUSTRATES

VIEWS OF SATURN BY DIFFERENT OBSERVERS FROM 1610 TO 1655 P. 83.
THE DIFFERENT APPEARANCES OF SATURN EVERY 30 YEARS &
THE CAUSE OF THOSE VARIOUS APPEARANCES. _ P. 84. 85.
THE STRUCTURE, DIMENSIONS &c. OF SATURNS RINGS &
THE APPEARANCE OF THE RINGS AS SEEN FROM DIFFERENT POINTS UPON THE BODY OF THE PLANET. P._86.

body of Saturn is of a *lead color*—the rings a *silvery white.*

Before the invention of the Telescope, Saturn was known only as a distant planet, devoid of that special interest with which modern discoveries have invested him. But since the powers of that wonderful instrument have been brought to bear upon him, he has assumed new and resplendent glories, and now stands forth to view as one of the most interesting objects in the gorgeous heavens.

Though we have no room in this treatise to describe the different kinds of telescopes, or to detail their history, we propose, nevertheless, to give some idea of their *improvement*, by tracing the *successive steps* by which we have arrived at our present knowledge of the planet Saturn.

The figures arranged across the top of Map 11 are representations of a variety of telescopic views of Saturn, by different observers, during a period of 45 years; or from 1610 to 1655. The variety in these appearances is probably owing more to the various qualities of the telescopes used, and their general imperfection at that early period, than to any other cause.

Fig. 1 is a view, had by *Galileo*, the inventor of the telescope, in the year 1610. He supposed there were two large satellites at equal distances from the body of Saturn.

Fig. 2 represents him as he appeared to *Scheiner* in 1614.

Fig. 3 is a view by *Riccioli*, in 1640. With the exception of the convexity towards the body of Saturn, the figure is a pretty correct one so far as the rings were traceable.

Fig. 4 represents Saturn as he appeared to *Helvetius* in 1643.

Fig. 5 is another view by Helvetius, in 1649. The rings were now traced much farther than ever before, and their existence *as rings* was considered highly probable.

Fig. 6 is a third, and still better view, by the same observer, in 1650.

Fig. 7 represents a fourth view by Helvetius, in 1650.

Fig. 8 is a most accurate and enchanting view had by Riccioli in 1651. It shows the rings of Saturn as they are often seen in our own times, through telescopes of moderate power. The remaining four representations, as they occur on the map, were all had in 1655: the first by *Fontani;* the second by *Divini;* the third by *Riccioli;* and the fourth by *Gassendus.*

The real appearance of Saturn, as seen through a common and cheap telescope, is well represented at A or B, immediately under the above views, with the exception of the opening between the rings. We have often seen him as here represented,—and with the belts across his disc as shown in Map 10,—and that, too, with an ordinary refracting telescope; but in earlier periods in the history of the science, such views were denied even to the most wealthy, devoted, and profound astronomers.

But this wonderful planet does not present the same appearance at all times, even with the aid of the best glasses. Indeed, the better the instrument the more perceptible his variations. In the course of 30 years, the time of his periodic revolution, he presents all the different phases shown at Fig. 3, from A to H. At one time the rings are entirely invisible, except as a dark stripe across the body of the planet, as seen at A. About 3¾ years afterwards the rings appear slightly opened, as at B; and in 3¾ years more they appear as at C, &c.

These different phases are all accounted for by Fig. 2. Here the sun is seen in his place in the centre, and the earth and Saturn in their orbits, as they may be supposed to appear to a beholder at a distance, and elevated somewhat above the plane of the ecliptic. This diagram may be used to illustrate a variety of principles.

1. It shows how the axis of Saturn (as well as that of the earth, &c.) *preserves its parallelism* in all parts of its orbit, and from age to age.

2. It illustrates the subject of his *seasons*, as partially explained in Lesson 55; and shows how the sun must shine on one side of his rings 15 years, and on the other 15 years. At A the light falls directly on the *edge* of the rings; but as soon as he passes that equinoctial point, the sun shines upon the *lower* or *southern* side of the rings, and continues to do so till the planet reaches its other equinox at E. Here the light crosses over to the *upper* or *north* side of the rings, upon which it continues for the

next 15 years; or till the planet passes round to A again.

3. It shows that the *Equinoxes* and *Solstices* are by no means peculiar to the earth—they belong to all the planetary bodies. In the figure, A and E are the *equinoctial*, and C and G the *solstitial* points.

4. The learner should test himself by this figure to see if he fully understands the subject of the *sun's declination*, as explained in Lesson 48.

5. As before said, this view of Saturn in his orbit accounts for all his different phases during his periodic journey, as shown at Fig. 3. Let the student suppose himself on the earth, where he really is, and watching Saturn in his course; and he will find that the rings must necessarily present all the variety in appearance which is seen in Fig. 3, as well as every intermediate degree of contraction and expansion.

Let this explanation be traced through. Take any particular position of Saturn, or take them in order, beginning at A, and it will be found that the view denoted by the corresponding letter in Fig. 3 must be the appearance *from the earth*, as she comes round between Saturn and the sun. At C the rings are thrown up, and hide the upper edge of the planet; while at G they seem inclined the other way, and the planet hides the upper edge of the rings, &c.

6. This diagram shows why we cannot see Saturn at all times in the year. Suppose him to be at C, for instance, on the first of January, and the earth on the same side of her orbit; of course he would be directly overhead, or rather on the meridian, at *midnight*, and might therefore easily be seen for six hours preceding, and six following that hour. In six months from that time, or by the first of July, the earth will have passed round to the point opposite G; but as Saturn has moved but a short distance apparently in his orbit, he will not only be above the horizon in the daytime, but nearly in conjunction with the sun. He must therefore be invisible till the earth again gets around where Saturn will be comparatively in opposition, or on the dark side of the earth.

Lesson 66.

DIMENSIONS, STRUCTURE, AND USES OF SATURN'S RINGS.

(Map 11.)

Diameter of the planet - - - -	79,000 miles.
Distance to the interior ring - - -	20,000 "
Width of the interior ring - - -	20,000 "
Opening between the rings - - -	2,000 "
Width of the exterior ring - - -	10,000 "
External diameter of the outer ring -	192,000 "
Thickness of the rings - - - -	100 "

Fig. 4 on the map is a *vertical* view of the rings of Saturn, or such as an observer would have if he were situated directly over either *pole* of the planet, and at a considerable distance from it. The opening between the rings, and between the planet and the rings, would then be visible all round, and of uniform width. Through these openings the stars would be as distinct as in any other portion of the celestial sphere; hence we have so represented in the figure.

Fig. 5 is a view of the rings as they would appear to an observer situated upon the body of the planet itself, and about half way from his equator to his north pole. This is a *summer* view, of course, as the rings are enlightened; whereas during winter in the northern hemisphere the rings would look dark, like the dark part of a new moon.

Under this gorgeous arch may be seen a portion of the planet's surface. On the right is a *new moon*, and on the left a *full moon*, both in view at the same time, one in the west and the other in the east. On the left, and crossing the rings, may be seen the *shadow* of Saturn, gradually ascending the arch as the night advances, till it reaches the zenith at midnight, and disappears in the west at the approach of day.

Fig. 6 is a similar view from the body of Saturn, the observer being located at a distance from the equator, or near his pole on the planet's surface. The arch would then appear low down in the south, and also more narrow and slender; and a much smaller portion of the rings would appear above the horizon. The following particulars may conclude this interesting lesson.

1. By observing the motion of certain spots or inequalities in the rings of Saturn, it has been ascertained that they *revolve* around the planet in 10¼ hours; or in the time of his diurnal revolution, (Lesson 21.)

2. That the rings are *solid matter*, like the body of Saturn, seems evident from the fact that they reflect the light of the sun very strongly, and cast a deep shadow upon the planet's surface.

3. Stars have sometimes been seen between the inner and outer rings, which proves them to be actually separated.

4. Of the *uses* of these wonderful rings it is sufficient to say that they serve as so many *reflectors* to the planet; and being only about $\frac{1}{24}$ part as distant as our moon, and of such vast magnitude, they must tend greatly to modify the *climate* of the planet, by contributing to the light and heat of his summer evenings. During the winter in each hemisphere, the rings *cast a shadow*, and increase the intensity of the cold.

HERSCHEL.

Upon this distant orb no spots have ever yet been discovered. It is supposed to be surrounded by an atmosphere; but even this is not certain. Through a telescope "we see nothing but a small, round, uniformly illuminated disc, without rings, belts, or discernible spots." It is of a pale ash color.

LE VERRIER.

Very little is known as yet of this new member of the solar family. We have therefore attempted no representation of its telescopic appearance upon the map. By the following letter, however, copied from the *London Times*, it appears that Le Verrier also may be adorned with a suit of gorgeous rings:

STARFIELD, Liverpool, Oct. 12, 1846.

On the 3d instant, whilst viewing this object with my large equatorial, during bright moonlight, and through a muddy and tremulous sky, I suspected the existence of a ring round the planet; and on surveying it again for some time on Saturday evening last, in the absence of the moon, and under better, though still not very favorable atmospherical circumstances, my suspicion was so strongly confirmed of the reality of the ring, as well as of the existence of an accompanying satellite, that I am induced to request you, as early as possible, to put the observations before the public.

The telescope used is an equatorially mounted Newtonian reflector, of 20 feet focus, and 24 inches aperture, and the powers used were various, from 316 to 567. At about 8¾ hours, mean time, I observed the planet to have apparently a very obliquely situated ring, the major axis being seven or eight times the length of the minor, and having a direction nearly at right angles to a parallel of declination. At the distance of about three diameters of the disc of the planet, northwards, and not far from the plane of the ring, but a little following it, was situate a minute star, having every appearance of a satellite. I observed the planet again about two hours later, and noticed the same appearances, but the altitude had then declined so much that they were not so obvious. My impression certainly was that the supposed satellite had somewhat approached, but I cannot positively assert it. With respect to the existence of the ring, I am not able absolutely to declare it, but I received so many impressions of it, always in the same form and direction, and with all the different magnifying powers, that I feel a very strong persuasion that nothing but a finer state of atmosphere is necessary to enable me to verify the discovery. Of the existence of the star, having every aspect of a satellite, there is not the shadow of a doubt.

Afterwards I turned the telescope to the Georgium Sidus, and remarked that the brightest two of his satellites were both obviously brighter than this small star accompanying Le Verrier's planet. WM. LASSELL.

In the periodical from which we copy, this statement of Mr. Lassell is accompanied by a *drawing*, representing the appearance of the planet as above described.

Lesson 67.

OF THE DISCOVERY OF THE SEVERAL PLANETS.

Mercury, *Venus*, *Mars*, *Jupiter*, and *Saturn*, have been known from the earliest ages in which astronomy has been cultivated.

The time, place, and discoverer of the asteroids, respectively, is as follows:—

Ceres, Jan. 1, 1801, by M. Piazzi, of Palermo.
Pallas, March 28, 1802, by M. Olbers, of Bremen.
Juno, Sept. 1, 1804, by M. Harding, of Bremen.
Vesta, March 29, 1807, by M. Olbers, of Bremen.
Astræa, Dec. 8, 1845, by Encke, of Dresden.
Hebe, July 5, 1847, by Encke, of Dresden.
Iris, Aug. 13, 1847, by Hind, of London.
Flora, Oct. 18, 1847, by Hind, of London.
Metis, April 25, 1848, by Graham, of Sligo.

Herschel was discovered by Sir William Herschel, March 13th, 1781.

Le Verrier, the new planet, was ***demonstrated to exist*** by M. Le Verrier, of France, in August, 1846. Its existence and locality being thus determined, it was first seen Sept. 23d, 1846, by Dr. Galle, at Berlin.

As the circumstances of this discovery are of the most interesting character, we subjoin the following letter upon the subject for the perusal of the student:

ESH, near Durham, Oct. 8, 1846.

But a few months have elapsed since the discovery of the small planet Astræa, the companion of the small planets Juno, Ceres, Pallas, and Vesta, already known. The last few days have brought us the intelligence of the discovery of another new planet, under circumstances so unexampled, as to form the most brilliant achievement of theoretical and practical astronomy. Some of your readers may be interested in a familiar explanation of the steps which have led to this interesting discovery.

The motions of all the planets are affected by the gravitation of the planets to one another; and the places of the planets in the heavens are computed beforehand, so that the positions given by observation can be constantly compared with those previously calculated. Now the observed motions of the planet Uranus, the most distant hitherto known in our system, when thus compared, were found not to agree with the motions which the planet would have, after allowing for the influence of all the known planets; and when it was found that the deviations were far greater than any which could be ascribed to mere errors of observation, that they were of a regular character, and of such a nature as would arise from the action of a still more distant planet, the attention of astronomers was directed to ascertain whether the disturbances were such as to point out the position of the disturbing planet. As long ago as the year 1842, a communication took place between Sir John Herschel and the lamented German astronomer, Bessel, on this subject: and there is reason to suppose that some researches on the subject will be found among Bessel's papers; for, in a letter written Nov. 14, 1842, to Sir J. Herschel, Bessel says, "In reference to our conversation at Collingwood, I announce to you that Uranus is not forgotten." The question was, however, taken up by other astronomers. Le Verrier, in France, and Mr. Adams, of St. John's College, Cambridge, in England, each in ignorance of each other's labors, proceeded to investigate this most intricate question, and arrived independently at the same conclusion, that the probable place of the suspected planet was about 325° of heliocentric longitude. This was sufficient to point out, within certain limits, the part of the heavens at which the planet, if visible, would be seen; and, in consequence, Professor Challis, at Cambridge, for the last two months, was engaged in mapping the neighboring stars with a view of detecting the planet. Sir John Herschel alluded to the probability that the planet would be detected in the speech which he made on resigning the chair at the late meeting of the British Association. Having observed that the last twelvemonth has given another new planet to our system, he added, "It has done more. It has given us the probable prospect of the discovery of another. We see it as Columbus saw America from the shores of Spain. Its movements have been felt, trembling along the far-reaching line of our analysis, with a certainty hardly inferior to that of ocular demonstration."

The eloquent and glowing anticipation of the future was soon to receive its accomplishment. On the 31st of August, Le Verrier made public the following elements of the orbit of the supposed planet, deduced by most laborious calculations from the observed disturbances:

Semi-axis major	36,154
Eccentricity	0,10761
Longitude of Perihelion .	284° 45′
Mean long. Jan. 1, 1847 .	318° 47′
Periodic time	217,387 sidereal years.
Mass	$\frac{1}{3900}$.

He also announced that the planet would probably present a disc of about 3″ in magnitude. This announcement reached Dr. Galle, at Berlin, on the 23d of September, and on the same evening Dr. Galle, on comparing the stars in Dr. Bremiker's chart with the heavens, found a star of the eighth magnitude which was not marked upon the map. The place of this star was accurately observed, and on comparing this place with its position on the following night, its motion, amounting to about 4° in right ascension, and 30′ in declination, was detected; and the star was proved to be the expected new planet.

It ought to be noticed that the new investigations of Le Verrier, accompanied with a recommendation to astronomers to search for the planet by examining whether any star presented a sensible disc, did not reach Cambridge till September 29, and that Professor Challis, on that very evening, singled out one star, as seeming to have a disc, and that star was the planet. Thus the theory, derived by a most abstruse calculation, from long-continued accurate observation, has been completely verified; and a triumph has been gained which will go down to posterity among the most brilliant of astronomical discoveries.

The known boundaries of our planetary system have thus been nearly doubled; a planet is added to it requiring more than 217 years to complete its revolution round the sun; and moving in regions so remote as to receive but $\frac{1}{1300}$th part of the light and heat which our earth enjoys.

It will remain to be discovered whether, as seems most probable, this planet is accompanied with a train of attendant satellites; whether its motions are in accordance with the known laws of gravitation; or whether it, in turn, is to serve as the means of a still further extension of the solar system.

There is one circumstance connected with this new planet which is too remarkable to be overlooked. It was long since noticed by Bode, that the distance of the planets from the sun follows a peculiar law, which may be thus stated—that if the distance of Mercury from the sun is assumed to be 4, the distance of Venus, the next planet, is 3 added to 4, or 7; that of the earth, which is next, *twice* 3 added to 4, or 10; and thus for the remaining planets, the distances from each other are *doubled* every time, as may be seen from the following table:

Name of Planet.	Dist. from the Sun.	Difference.
Mercury	4	3
Venus	7	3
Earth	10	6
Mars	16	12
Small Planets . .	28	24
Jupiter	52	48
Saturn	100	96
Uranus	196	192
New Planet . . .	388	

The distance of the new planet then approximately satisfies this very remarkable law; and the little stranger is at once recognised as bearing a strong family likeness to the other members of our system.

TEMPLE CHEVALLIER.

From the calculation submitted in the foregoing accounts it appears that the Le Verrier planet must be nearly *three thousand millions of miles* from the sun! Verily, such a discovery is "enlarging the boundaries of the Solar System" most effectually. But what is this distance after all, when we consider that it would require more than 6000 such journeys to reach the nearest of the fixed stars?

CHAPTER III.

OF THE SECONDARY PLANETS.

Lesson 68.

CHARACTER AND NUMBER OF THE SECONDARY PLANETS.

(Map 2.)

THE *secondary planets* are those comparatively small bodies that accompany the primaries in their course, and revolve around them. As the primaries revolve around the sun, so the secondaries revolve around their primaries.

The number of secondary planets positively known to exist is *nineteen*. Of these, the Earth has *one*, Jupiter *four*, Saturn *eight*, and Herschel *six*. They may be seen on the map at their relative distances from their primaries. Their relative *magnitudes* are also represented.

Though the secondary planets have a compound motion, and revolve both around the sun and around their respective primaries, they are subject to the same general laws of gravitation—of centripetal and centrifugal force

—by which their primaries are governed. Like them, they receive their light and heat from the sun, and revolve periodically in their orbits, and on their respective axes. In the economy of nature they seem to serve as so many *mirrors* to reflect the sun's light upon superior worlds, when their sides are turned away from a more direct illumination. The secondary planets are generally called *moons*, or *satellites*.

Lesson 69.

SUPPOSED SATELLITE OF VENUS.

Several astronomers have maintained that Venus is attended by a satellite. From the observations of Cassini, Mr. Short, Montaigne, and others, as quoted by Dr. Dick,* it seems highly probable that such a body exists. M. Lambert supposed its period to be 11 days, 5 hours, and 13 minutes; the inclination of its orbit to the ecliptic 63¾°; its distance from Venus about 260,000 miles; and its magnitude about ¼ that of Venus. It is to be hoped that this interesting question will ere long be fully settled, as it is one which numerous telescopes, both in this country and in Europe, have capacity to decide. It is a question worthy of the attention of Lord Rosse, and the powers of his colossal reflector.

Lesson 70.

OF THE EARTH'S SATELLITE OR MOON.

(Map **12**.)

To ordinary observers of the heavens, the moon is an object of great interest. Her nearness to the earth—her magnitude—her rapid angular motion eastward—her perpetual phases or changes, and the mottled appearance of her surface, even to the naked eye, all conspire to arrest the attention, and to awaken inquiry. Add to this her connection with *Eclipses*, and her influence in the production of *Tides*, (of both of which we shall speak hereafter in distinct chapters,) and she opens before us one of the most interesting fields of astronomical research.

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* Celestial Scenery, pp. 84–89.

The following table exhibits the principal statistics and facts respecting the moon, and should be carefully studied or committed to memory.

Mean distance from the earth's centre	240,000 miles.
Sidereal revolution - - - -	$27\frac{1}{3}$ days.
Synodic revolution - - - -	$29\frac{1}{2}$ "
Periodic revolutions per year, nearly -	13
Direction in orbit from west to east.	
Hourly motion in orbit - - -	2,300 miles.
Mean angular motion per day -	13° 10′ 35″
Diameter - - - - -	2,160 miles.
Apparent angular diameter - -	31′ 7″
Bulk, as compared with the earth -	$\frac{1}{49}$
Bulk, as compared with the sun -	$\frac{1}{70,000,000}$
Surface, as compared with the earth -	$\frac{1}{13}$
Density, the earth being 1 - -	$\frac{2}{3}$
Inclination of orbit to the ecliptic -	5° 9′
Eccentricity of orbit - - -	13,333 miles.
Longitude of ascending node - -	variable.
Inclination of axis to orbit - -	$1\frac{1}{2}$°
Revolution upon axis - - -	$29\frac{1}{2}$ days.
Light reflected by her, as compared with that of the sun - - -	$\frac{1}{300,000}$

By comparing the *distance* of the moon, as expressed in the foregoing table, with that of the sun, (Lesson 8,) it will be seen that the latter is four hundred times as far off as the former. It is for this reason that she generally appears as *large* as the sun, when in fact he is seventy million times the largest. The moon may therefore well be regarded as our nearest terrestrial neighbor.

It may also be interesting to compare the *angular magnitude* of the moon as seen from the earth, with that of the sun, as given in Lesson 11. They seem to differ but 53″; or less than one minute of a degree. Thus the sun, on account of his immense distance, looks no larger than the moon; when in fact he is equal in bulk to *seventy millions* of such bodies.

If the student does not fully understand the *cause* of this agreement in the apparent magnitude of the sun and moon, when they are in reality so disproportionate in bulk, let him turn back and review Lesson 10, and the map and figure therein referred to.

Lesson 71.

CHANGES OR PHASES OF THE MOON.

(Map 12.)

The upper row of figures on the map represents the changes of the moon in passing from new to full moon, and around to new moon again. The first figure on the right represents the *new moon*, when, if visible at all, we see only her dark side. She is then at her *conjunction*, or in the same longitude with the sun, and to ordinary observers is invisible. As she advances eastward in her orbit, she falls behind the sun in his apparent daily course, and in a few days is seen in the west just after sundown, in the form of a slender crescent, as seen in the next view to the left. As she advances, we see more and more of her bright side, as represented on the map, till she reaches her *opposition*, when her enlightened hemisphere is towards us, and we see her as a *full moon*.

From this time onward the *west* side of the moon begins to be obscured, for want of the sun-light, and the crescent begins to be inverted. From the first quarter to the full, and from full moon to the last quarter, the moon is said to be *gibbous*.

The *cause* of these changes is further illustrated in Figure 2, where the earth is shown in the centre, and the moon at various points in her orbit. The sun is supposed to be on the right, as in Figure 3. The outside suit of moons shows that in fact just one half of the moon is always enlightened; while those on the inside show *how much* and *which part* of her enlightened side is

MAP No. 12.

PHASES AND TELESCOPIC VIEWS OF THE MOON.

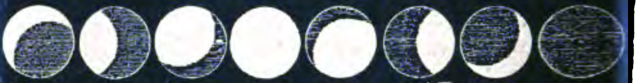


FIG. 2.

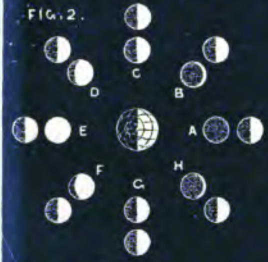
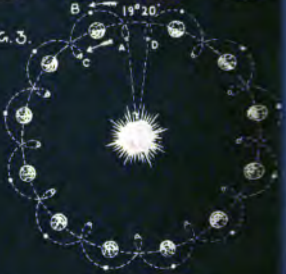
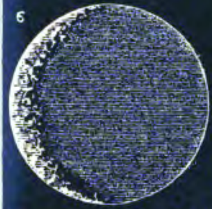


FIG. 3.



6



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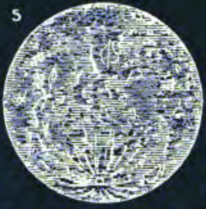

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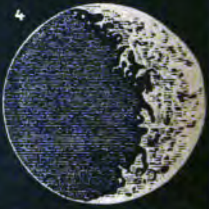

THIS MAP ILLUSTRATES

THE CHANGES OR PHASES OF THE MOON. _ _ _ P. 96.
THE MOONS REVOLUTION AROUND THE EARTH, & SUN 97
THE REVOLUTIONS OF THE LUNAR NODES WESTWARD AROUND THE ECLIPTIC & HER SIDERIAL & SYNODIC REVOLUTIONS. _ _ _ _ _ _ _ _ _ _ _ P. 98.
THE TELESCOPIC APPEARANCE OF THE MOON, HER PHYSICAL CONSTITUTION, MOUNTAINS, &c. P. 100, 101
THE GEOGRAPHY OF THE MOON, OR SELENOGRAPHY. 103

[illegible] *from the earth.* A is the new moon. B shows her [illegible] first visible. C is the first quarter; D gibbous; E [illegible] moon ; F gibbous ; G last quarter ; H the crescent verted ; and A new moon again. This revolution of [illegible] moon around the earth, is called a *lunation*.

The points A and E, in the moon's orbit, are called r *syzygies ;* C and G her *quadratures ;* and B, D, F, d H, her *octants*.

Lesson 72.

THE MOON'S PATH AROUND THE SUN.

(Map 12.)

The revolution of the moon around the earth, and with e earth around the sun, is represented by Fig. 3.* As r orbit nearly coincides with the ecliptic, she is some-mes *within*, and at others *without* the earth's orbit. When e moon is at A, and the earth in her orbit between A d 19, it is *new moon.* In about 14 days she reaches B, d will be seen from the earth as a *full moon.* In 14 ys longer she reaches C, when it is new moon again, nd so on perpetually. At A she is in *conjunction*, and t B in *opposition*.

But it will be seen that the twelve revolutions of the moon and the one revolution of the earth *do not come out even ;* or in other words, do not end at the same time. From the new moon at A, around to the new moon at D, re just twelve lunar months or revolutions ; but at this me the earth wants 19° 20′ to reach her starting-point at A, or to complete her year. The lunar year, therefore, consisting of twelve synodical revolutions of the moon, or 346 days, is 19 days shorter than the civil year.

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* The author is aware that the figure does not represent the actual [illegible] of the moon around the sun, neither is it possible to draw it, ex-t upon a very large scale. The moon *never retrogrades*, but is vancing with the earth at the rate of 65,000 miles an hour, even new moon, and when falling behind the earth. When in opposi-n, and gaining upon the earth, her velocity is about 71,000 miles hour. The true path of the moon would appear almost parallel that of the earth, which it would cross backward and forward, at ery acute angles, every 14½ days, or at intervals of about 14½° each. ut even the portion *within* the earth's orbit would *be concave to-wards the sun.* The diagram, Fig. 3, inculcates *more truth* and *less rror* than any other we could employ, and we use it for the same eason that we find it in Burritt's Atlas, and in Mitchel's edition of the Geography of the Heavens.

Lesson 73.

REVOLUTION OF THE MOON'S NODES AROUND THE ECLIPTIC.

(Map 12.)

By referring to Lessons 30 and 31 it will be seen that the nodes of Mercury and Venus are permanent; that is, that they are always at the same point in the ecliptic, or in the same longitude. But this is not the case with the moon's nodes. Suppose the line passing down from A, Fig. 3, to represent the line of her nodes, at the commencement of a lunar year. After twelve lunations, and when she has passed round to the point D, she will have returned to the same node again, although she is 19° 20′ short of the point where that node was reached 346 days before. At this time the line passing down from D would represent the line of her nodes. In this manner the nodes of the moon's orbit fall back westward, or recede 19⅓° every lunar year, till they complete a backward revolution quite around the ecliptic. To do this requires 18 years and 225 days, or 223 lunations; when the moon will reach the same node again at D, or in the same longitude.

This revolution of the moon's nodes will be noticed again in the chapter on *Eclipses*. The motion of the *apsides* will also be explained and illustrated in the chapter on *Tides* in connection with Map 14.

Lesson 74.

SIDEREAL AND SYNODIC REVOLUTION OF THE MOON.

(Map 12.)

The difference between a *sidereal* and *synodic* revolution of the planets is explained in Lesson 57. A *sidereal* revolution of the moon is a revolution from a particular star, around to the same star again; or what would constitute a complete revolution if the earth were at rest. But as the earth is constantly advancing in her orbit, the moon, in passing from one full moon to another, has to perform *a little more* than a complete revolution to bring her again in opposition to the sun. This extended journey is called her *synodic* revolution.

The sidereal period is 27⅓ days, and the synodic 29½, as already stated, Lesson 70.

Lesson 75.

REVOLUTION OF THE MOON UPON HER AXIS.

(Map **12.**)

From the uniform appearance of the moon's surface, even to the naked eye, it is obvious that she always presents nearly the same side to the earth. From this fact it is concluded that she makes but one revolution upon her axis during her synodic revolution—that her motion upon her axis is from west to east—that her day (including a lunar day and night) must be equal to 29½ of our days; and that the earth is always invisible from one half of the moon's surface.

By consulting Fig. 2, it will easily be seen that to keep the same side towards the earth, the moon must necessarily revolve once on her axis during her synodic revolution; and also that if the side towards the earth at the full was towards us also at new moon, the side in darkness at full moon would be towards the sun, or enlightened at new moon. Observe, we are speaking of her *actual* light and shade, and not of her appearance from the earth.

Lesson 76.

THE MOON'S LIBRATIONS.

(Map **12.**)

Though the moon always presents nearly the same hemisphere towards the earth, it is not always *precisely* the same. Owing to the ellipticity of her orbit, and the consequent inequality of her angular velocity, she appears to *roll* a little on her axis, first one way and then the other, thus alternately revealing and hiding new territory, as it were, on her eastern and western limbs. This rolling motion east and west is called her *libration in longitude*.

The inclination of her axis to the ecliptic gives her another similar apparent motion, alternately revealing and hiding her *polar regions*. This is called her *libration in latitude*. It may be illustrated by Map 4, Fig. 2, as explained in Chapter VI.

Lesson 77.

SEASONS OF THE MOON.

The moon's year consists of 29½ of our days; and as she revolves but once on her axis in that time, it follows that she has but *one day* and *one night* in her whole year. So slight is the deviation of her orbit from the plane of the ecliptic, and the inclination of her axis to the plane of her orbit, that the sun's declination upon her can never exceed 6° 40′. She must therefore have perpetual winter at her poles, while at her equator her long days are very warm, and her long nights very cold.

Lesson 78.

TELESCOPIC VIEWS OF THE MOON.

(Map 12.)

Fig. 4 is a telescopic view of the moon, as she appears when about a week old. The ragged line dividing her illuminated from her dark hemisphere, and extending around the moon, is called the *circle of illumination;* and the portion of this circle towards the earth, as represented on the map, is called the *Terminator*. This line traverses the moon's disc from west to east in about 15 days, when it disappears from her eastern limb; and the other half of the circle of illumination immediately appears on her western border. In about 15 days longer, it passes around to the eastern limb again, as represented at Fig. 6, and at the change of the moon entirely disappears.

The Figures 4, 5, and 6, are faithful representations of the moon, as she appears through a telescope of moderate power, at three different periods during a lunation.

Lesson 79.

PHYSICAL CONSTITUTION OF THE MOON—MOUNTAINS, VOLCANOES, ATMOSPHERE, ETC.

(Map **12.**)

Nothing is more obvious, from a telescopic view of the moon, than that her surface is remarkably *rough* and *uneven*. The evidence of this is,

First, the crooked and ragged appearance of the *terminator*. Were the moon's surface level and smooth, this line would be uniform, and sharply defined.

In the *second* place, small bright spots appear from time to time, from new to full moon, *beyond* the terminator, in the dark portions of the moon's disc. These are never far from the terminator, and grow larger and larger as it approaches them. In the same manner these bright spots linger *after* the terminator, from full to new moon, and grow smaller and smaller till they disappear.

In the *third* place, after these spots fall fairly within the enlightened hemisphere of the moon, they project a *shadow* towards the terminator, or in a direction opposite to the sun. From new to full moon these shadows all point *eastward*, while from full to new moon again they all point *westward*.

Now nothing can be more certain, from all these phenomena, than that the moon is covered with *mountains*. Being elevated above the common level of the moon's surface, the sun's light would fall upon their summits before the surrounding valleys were rendered luminous or visible by reflected light. As the light advanced eastward it would enlarge the visible portions of the mountains; and finally, after the space around them, west, north, and south, was enlightened, they would still cast shadows eastward. Besides, these shadows are always darkest on the side towards the sun, or nearest the mountains.

By examining Figures 4 and 6, in connection with the foregoing remarks, the student can hardly fail to be satisfied that the moon also has her Alps, her Andes, and her Pyrenees. Some of her mountains have been estimated to be five miles in height.

It has been ascertained also that many of the lunar mountains are of *volcanic formation*, like Etna and Vesuvius. Dr. Herschel states that he actually saw the light of the *fires* of several active volcanoes in the moon. The extravagant statement made by some authors, that *cities*, *fortifications*, and *roads* have been seen on the moon's disc, is worthy of little or no credit. It is much easier to *imagine* cities, &c., to exist on the moon's surface, than to actually *see* them even if they were there.

In regard to the existence of an *atmosphere* around the moon, astronomers are divided. From observations during eclipses of the sun, and other phenomena, it is thought that if the moon has any atmosphere at all, it must be very limited in extent, and far less dense than that of the earth.

Dr. Scoresby, of Bradford, England, has published a description of the moon, as she appears through the monster telescope of Lord Rosse. He represents her as appearing in great magnificence through this famed instrument, seeming like a globe of molten silver, whilst every object of the extent of one hundred yards was quite visible, and edifices of the size of York Minster, might therefore, he said, be easily perceived if they had existed. He states however, that there was no appearance of any thing of that nature, neither was there any indications of the existence of water, nor of an atmosphere. There was a vast number of distinct volcanoes, several miles in breadth; through one of them there was a line in continuance of one, about one hundred and fifty miles in length, which ran in a straight direction like a railway. The general appearance, however, was like one vast ruin of nature; and many of the pieces of rock, driven out of the volcanoes, appeared to be laid at various distances.

Lesson 80.

GEOGRAPHY OF THE MOON, OR SELENOGRAPHY.

(Map **12.**)

The great natural divisions of the moon's disc have received appropriate names. The following is a list of some of her principal *mountains*, and their height, according to the recent measurement of Mädler:

	Feet.	Miles.
Posidonius	19,830	3.76
Tycho	20,190	3.83
Calippus	20,390	3.86
Casatus	22,810	4.32
Newton	23,830	4.52
Clavius	19,030	3.60
Huygens	18,670	3.54
Blancanus	18,010	3.41
Movetus	18,440	3.49

The following list may be found upon the map, Fig. 5, the numbers in the drawing answering to those of the table. It may require a near view to read the figures on the map.

1. Tycho,
2. Kepler,
3. Copernicus,
4. Aristarchus,
5. Helicon,
6. Eratosthenes,
7. Plato,
8. Archimedes,
9. Eudoxus,
10. Aristotle.

The dusky portions formerly supposed to be *seas*, are designated as follows:—

A. Mare Humorum,
B. " Nubium,
C. " Imbrium,
D. " Nectaris,
E. Mare Tranquilitatis,
F. " Serenitatis,
G. " Fecunditatis,
H. " Crisium.

MM. Baer and Mädler, of Berlin, have constructed a map of the moon, which is characterized by Professor Nichol of Glasgow, as "vastly more accurate than any map of the earth we can yet produce," and as "the only authentic and valuable work of the kind in existence." Fig. 5 on the map is a faithful transcript of this invaluable drawing of the moon's surface.

The subject of *Eclipses* and *Occultations* will be considered in Chapter IV.; and that of *Tides* in Chapter V.

Lesson 81.

MOONS OR SATELLITES OF JUPITER.

(Map 2.)

Jupiter has four satellites, whose distances, magnitudes, and periodic times are as follows:—They are numbered in order, beginning with the one nearest to their primary.

	Diameter in miles.	Distance.	Periodic times.
1st	2,500	259,000	1 day 18 hours.
2d	2,068	414,000	3 " 12 "
3d	3,377	647,000	7 " 14 "
4th	2,890	1,164,000	17 " 0 "

By comparing the *magnitude* of Jupiter's satellites, with that of our moon, Lesson 70, a striking resemblance will be discovered. Indeed the *size* and *distance* of the first answer almost exactly to the size and distance of the moon. But when we come to the *periodic times*, we find a vast disproportion. So great is the mass and attractive force of Jupiter, that if even his most distant satellite had a periodic revolution of twenty-nine and a half days, its centripetal would overcome its centrifugal force, and it would fall to the body of the planet. To balance the great attractive force of the planet (Lesson

17) it is necessary that his secondaries should have a rapid projectile motion; hence, though the first is as large, and as distant from Jupiter as our moon is from the earth, it revolves more than *fifteen times* as rapidly as the moon. For remarks on the centripetal and centrifugal forces, see Lesson 20.

The moons of Jupiter revolve nearly in the plane of his equator, and of course, nearly in the plane of his orbit and of the ecliptic. See 32 and 50. Their orbits, as stated by Dr. Herschel, are inclined to the plane of his equator, as follows:

1st	3° 5′ 30″.
2d	Variable.
3d	Variable.
4th	2° 58′ 48″.

The eccentricities of the 1st and 2d are not perceptible. That of the 3d and 4th is small, and variable, in consequence of mutual perturbations, caused by their mutual attraction. They all revolve from west to east, or in the direction of the revolution of their primary upon his axis.

The satellites of Jupiter may be seen with a telescope of very moderate magnifying power, or a common spyglass; and one of them has even been seen with the naked eye. This noble planet with his retinue of moons is the solar system in miniature; and furnishes the most glorious confirmation of the truth of the Copernican theory.

For *eclipses* of Jupiter's satellites see the chapter on eclipses.

Lesson 82.

SATELLITES OF SATURN.

(Map 2.)

The satellites of Saturn are eight in number,* and are seen only with telescopes of considerable power. They revolve from west to east. The orbits of the six interior world is attended by one or more secondary bodies. Indeed we might almost infer this from analogy, especiall when we consider the *magnitude* of the planet as answering pretty nearly to that of Herschel; and his *immens distance* from the sun, upon which he also must depen for light and heat. This latter circumstance alone woul seem to demand a profusion of moons to arrest the su beams in the surrounding space, and reflect them upo the cold and cheerless bosom of their primary. For th present, however, the learner must content himself wit the little we are able to communicate upon this subjec in the hope that future observations may furnish us wit a more satisfactory knowledge of the economy and pec liarities of this far-distant orb.

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* The *eighth* has recently been discovered.

The secondary planets are all supposed to revolve o their respective axes, in the time of their periodic revolu tions, so as always to present the same hemispheres t their respective primaries. No smaller bodies have ev been discovered revolving around the *satellites*, as moo or satellites to them.

CHAPTER IV.

PHILOSOPHY OF ECLIPSES.

Lesson 85.

NATURE AND CAUSES OF ECLIPSES.

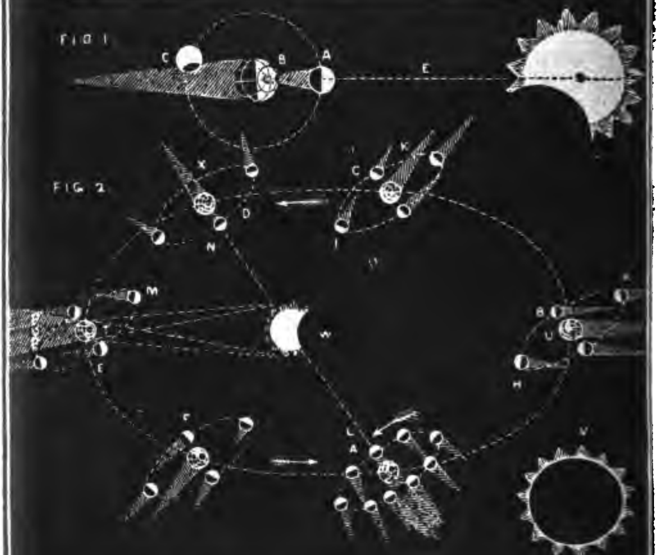
(Map 13.)

An *Eclipse* is the partial or total *obscuration* or *darkening* of either the sun or moon. An eclipse of the su is called a *Solar* eclipse, and that of the moon a *Luna* eclipse.

To understand the nature and philosophy of eclipses, i will be necessary to begin with what is called *the law of shadows*. The principles of this law are as follows:—

MAP No. 13.

SOLAR AND LUNAR ECLIPSES.



THIS MAP ILLUSTRATES

THE NATURE & CAUSES OF ECLIPSES. . . . P. 108-9.
THE CAUSES OF THE VARIETY OF SOLAR ECLIPSES. 110.112.
WHY LUNAR ECLIPSES VARY IN THEIR EXTENT DURATION &c 114
WHY WE HAVE NOT TWO ECLIPSES REGULARLY EVERY MONTH . 115.
WHAT IS MEANT BY THE ECLIPTIC LIMITS . . P. 116
THE RETROGRESSION OF THE MOON'S NODES, NODE MONTHS &c 116

A *shadow* is a portion of space deprived of light by the intervention of some dark or intransparent body.

The *length* and *form* of shadows depend not only on the form of the opaque body, by which the light is intercepted, but also upon its *magnitude* as compared with the luminous body; and its *distance from it.* At Fig. 1 the sun is seen at S, on the right, the earth at B, and the moon at A and C. The shadows of the earth and moon are seen projecting to the left, and running to a point. They have this form because the earth and moon are *smaller* than the sun; and as the earth is a *globe,* her shadow assumes the form of a *cone,* with its base towards the sun.

If the earth were *just as large* as the sun, her shadow would be in the form of a *cylinder;* and if *larger* than the sun, it would spread out like a fan; or like the section of a cone with its base turned *from* the sun. These principles may be illustrated at leisure by a candle and several balls of different sizes.

When the opaque body is *smaller* than the luminous one, the *length* of its conical shadow will depend upon its distance from the source of light. Thus, if the earth were at [illegible] Fig. 1, her shadow would be shorter than represented in the figure, by one half.

The shadow cast by the earth is darker in some parts than in others. This is represented at O, and P P, Fig. 2. The deep conical shadow shown at O, and in all the other figures, is called the *Umbra;* and the faint shadow shown at P P, the *Penumbra.*

We are now prepared to state the *causes* of eclipses:

An Eclipse of the sun is caused by the moon passing between the earth and the sun, and casting her shadow upon the earth. This is represented at A, B, Fig. 1, where the moon is seen passing in her orbit around the earth, and hiding part of the sun's disc at S, from the observer at B; or, what is the same thing, casting her shadow upon the earth at B. As the moon is moving eastward, or in the direction of the arrows, she covers the lower or *western* limb of the sun first, and advances to the east. By turning the right side of the map uppermost for a moment, and placing it to the south of the learner, the figure can hardly fail to give him a correct idea of the manner in which a solar eclipse is produced, and the reason why it always commences on the sun's western limb.

2. *Eclipses of the moon* are caused by her falling into the *earth's* shadow, as represented at C. These always commence on the moon's *eastern* limb, as may be shown by turning the *left* side of the map uppermost.

3. In its natural position the map illustrates another fact: it shows why eclipses of the sun always happen at *new* moon, and eclipses of the moon at *full* moon. To an observer on the earth the moon must be *new* at A, and *full* at C.

Lesson 86.

CHARACTER, EXTENT, AND DURATION OF SOLAR ECLIPSES.

(Map 13.)

1. The first thing to be determined in regard to solar eclipses is the length of the moon's shadow. Let the student now call to mind the fact that the earth and moon both move in elliptical orbits, as stated in Lessons 43, 45, and 70. Let him remember also, that the sun is in one of the foci of the earth's orbit, as represented in Fig. 2; and that the earth is in one of the foci of the *moon's* orbit, as shown at T and U. Now as the earth is farther from the sun at U than at T, her shadow will be longer; and so with the moon. The shadows of both are much longer when the earth is at or near her *aphelion*, as at U, than when near her *perihelion*, as at T.

2. The length of the moon's shadow is also modified by her position in her orbit. As her mean distance from the earth's centre is 240,000 miles, she must be 480,000 miles nearer the sun at new moon, than at her full. This difference in her distance must have its effect in lengthening or shortening her shadow. At T, Fig. 2, the earth is at her *perihelion*, and her shadow and that of her satellite are comparatively short. At U the earth is at her

most distant point from the sun; and the shadows of both the earth and the moon are proportionally elongated.

3. A *third* circumstance modifying the length of the moon's shadow, is the position of *her aphelion* and *perihelion* points, in respect to the sun. When the earth is at T, in her orbit, and the moon at her aphelion at M, which is then *towards* the sun, her shadow is the shortest possible; as she is then *nearer* the sun than at any other time; but when the earth is at her aphelion at U, and the moon comes to her aphelion when it is turned *from* the sun as at K, her shadow has its *greatest* possible length. Such is the variety of causes which conspire to affect the length of the shadows projected by the earth and moon.

4. When the earth is at U, and the moon at her perihelion, and in conjunction as at H, her shadow will extend 19,000 miles beyond the earth; and will be nearly 175 miles in diameter at the distance of the earth's surface. Consequently if her shadow fall *centrally* upon the earth, it will cover an area 175 miles in diameter, within which the sun will appear *totally* eclipsed. At this time the *penumbra* will cover an area 5,000 miles in diameter, within which the eclipse will be only *partial.* If the shadow falls upon the *side* of the earth, it will of course cover a much larger space; and in either case, it will move from west to east over the earth's surface.

5. When the earth is at T, and the moon at M, the shadow of the moon will not reach the earth by 20,000 miles; and when the sun and moon are at their *mean* distances from the earth, the cone of the moon's shadow will terminate a little before it reaches the earth's surface.

6. The angular or apparent magnitude of a body depends much upon its distance from the observer, (Lesson 10.) When the sun and moon are at their mean distances, they appear nearly of a size; but when the earth is at U, and the moon at H, the moon appears larger than the sun, and if a central eclipse take place, it will be *total;* or, in other words, the moon will entirely cover or hide the sun's face. This is owing to the

nearness of the moon to the earth, and the distance of the sun. A total eclipse may last 7 minutes and 58 seconds.

7. When the earth is at T, and the moon at M, the sun, being at his perihelion distance, will appear *unusually large;* and the moon being in apogee, will appear *unusually small.* Should a central eclipse happen at this time, the moon would not be large enough to hide the entire face of the sun, even when directly between us and him; consequently in the middle of the eclipse the moon would be seen covering the *centre* of the sun, and leaving a luminous ring unobscured, as represented at V on the map. This is called an *annular* eclipse; and the ring may last 12 minutes and 24 seconds.

8. For convenience in describing eclipses, the diameter of the sun and moon, respectively, is divided into twelve parts called *digits.* Thus at W, the sun would be described as about three digits eclipsed; at S, about four digits, &c.

The learner will now understand the difference between *partial* and *total, central* and *annular* eclipses. Both annular and total eclipses must be *central,* but the annular eclipse is not *total.* The ring or outer border of the sun is left unobscured.

"The following is a list of all the solar eclipses that will be visible in Europe and America during the remainder of the present century. To those which will be visible in New England the number of digits is annexed.

Year.	Month.	Day and Hour.	Digits.
1847,	Oct.	9 1 0 A. M.	
1848,	Mar.	5 7 50 A. M.	6⅙
1851,	July	28 7 48 A. M.	3⅔
1854,	May	26 4 26 P. M.	11⅓
1858,	Mar.	15 6 14 A. M.	1⅔
1859,	July	29 5 32 P. M.	2½
1860,	July	18 7 23 A. M.	6⅓

Year.	Month.	Day and Hour.	Digits.
1861,	Dec.	31 7 30 A. M.	4½
1863,	May	17 1 0 P. M.	
1865,	Oct.	19 9 10 A. M.	3⅗
1866,	Oct.	8 11 12 A. M.	0
1867,	Mar.	6 3 0 A. M.	
1868,	Feb.	23 10 0 A. M.	
1869,	Aug.	7 5 21 A. M.	10¼
1870,	Dec.	22 6 0 A. M.	
1873,	May	26 3 0 A. M.	
1874,	Oct.	10 4 0 A. M.	
1875,	Sept.	29 5 56 A. M.	11½
1876,	Mar.	25 4 11 P. M.	3⅜
1878,	July	29 4 56 P. M.	7⅓
1879,	July	19 2 0 A. M.	
1880,	Dec.	31 7 30 A. M.	5½
1882,	May	17 1 0 A. M.	
1885,	Mar.	16 0 35 A. M.	6½
1886,	Aug.	29 6 30 A. M.	0¼
1887,	Aug.	18 10 0 P. M.	
1890,	June	17 3 0 A. M.	
1891,	June	6 0 0 Mer.	
1892,	Oct.	20 0 19 P. M.	8⅕
1895,	Mar.	26 4 0 A. M.	
1896,	Aug.	9 0 0 Mer.	
1897,	July	29 9 8 A. M.	4½
1899,	June	8 0 0 Mer.	
1900,	May	28 8 9 A. M.	11

The eclipses of 1854, 1869, 1875, and 1900, will be very large. In those of 1858, 1861, 1873, 1875, and 1880, the *sun will rise eclipsed.*

Those of 1854, and 1875, will be *annular.* The scholar can continue this table, or extend it backwards, by adding or subtracting the Chaldean period of 18 years, 11 days, 7 hours, 54 minutes, and 31 seconds.*"

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* Ferguson.

Lesson 87.

ECLIPSES OF THE MOON.

(Map **13.**)

1. The average *length* of the earth's shadow is 860,000 miles; or more than three times the moon's average distance from the earth. Its average *breadth* at the distance of 240,000 miles from the earth's centre, or where the moon passes it, is about 6,000 miles; or three times the moon's diameter. Now the *extent* and *duration* of a lunar eclipse must depend upon these three circumstances:

(1.) The distance of the *earth* from the *sun*, and the consequent length of her shadow at the time.

(2.) The distance of the *moon* from the *earth*, which determines the diameter of the earth's shadow where the moon passes it; and

(3.) The *manner* in which she passes through the earth's shadow. If it be greatly elongated, it will be proportionably *larger* at the average distance of the moon's orbit; and if the moon is in perigee, and passes *centrally* through the earth's shadow, as at G and X, Fig. 2, the eclipse will be *total*, and *long continued*. On the other hand, if the moon is in apogee, she will pass the earth's shadow where it is comparatively slender, as at K, and the eclipse will be of comparatively short duration.

So if she pass through the *side* of the shadow, instead of its centre, the eclipse will be *partial* instead of total. An eclipse of the moon can never be annular, as she cannot get so far off that the earth's shadow would be insufficient, when centrally passed, to cover the whole of the moon's disc.

2. Before the moon enters the earth's shadow or *umbra*, as at O, the earth begins to intercept from her portions of the sun's light, or to cast a faint shadow upon her. This shadow, called the moon's *penumbra*, grows darker and darker as she advances, till she enters the conical and perfect shadow of the earth. Here the real eclipse begins. The umbra and penumbra may be seen at O, and P P, on the map.

Lesson 88.

OF THE TIME AND FREQUENCY OF ECLIPSES.

(Map **13.**)

1. If the moon's orbit lay in the plane of the ecliptic, as represented at Fig. 1, there would be two central eclipses every month; viz., one of the sun and one of the moon. But as the moon's orbit is inclined to the ecliptic at an angle of 5° 9′, (Lesson 70,) it is evident that she may be either *above* or *below* the ecliptic at the time of her conjunction with the sun; so that she will seem to pass either *above* or *below* him, and will not cause an eclipse. This will be understood by carefully observing the moon's orbit at M and H, Fig. 2. At M, the side towards the sun appears *thrown up* or *above* the ecliptic; while at H it is *below* the ecliptic. Of course, then, the moon's *shadow* will pass *below the earth*, as represented at H; and though it be ever so long, there will be no eclipse. For the same reason, the moon may pass either above or below the earth's shadow, at the time of her *opposition*, and no lunar eclipse occur.

2. It is only when the moon is *at* or *near* one of her *nodes*, that either a solar or lunar eclipse can occur. On the Map, Fig. 2, the line L N represents the line of the nodes, as well as the plane of the ecliptic. At A, the moon is seen coming to her node, in the direction of the arrow, and casting her shadow upon the earth. At the same time we see the eclipse advancing in the same direction, commencing upon the sun's western limb at W. At G and X, in the same figure, we see the moon totally eclipsed. If, therefore, the earth and the moon reach the line of the moon's nodes at the same time, the eclipse will be *central*, whether it be of the sun or moon.

3. But it is not necessary that the earth and moon should be *precisely* on the line of the moon's nodes, in order to produce an eclipse. "The distance of the moon from her node when she just touches the shadow

of the earth, in a lunar eclipse, is called the *Lunar Ecliptic Limit;* and her distance from the node in a solar eclipse, when the moon just touches the solar disc, is called the *Solar Ecliptic Limit.* The Limits are respectively the farthest possible distances from the node at which eclipses can take place."*

The *Lunar Ecliptic Limit* is 11° 25′ 40″. This is the greatest distance from the moon's node at which a lunar eclipse can take place; and in the event of its happening at such a distance from the node, it must be exceedingly small or slight.

The *Solar Ecliptic Limit* is 16° 59′. If at the moment of new moon her node be more than this distance from the sun, no eclipse can happen.

This subject may be elucidated by contemplating the moon as seen in her orbit at A, Fig. 2. As she approaches her node, it is evident that she will overlap or eclipse the sun, as soon as she gets within half the sun's diameter of the ecliptic; as just one-half of the sun is above the ecliptic. That point, therefore, in the moon's orbit which is only the semi-diameter of both the sun and moon from the ecliptic, is the *ecliptic limit* for solar eclipses.

4. The moon's nodes constantly fall back westward on the ecliptic, at the rate of about 19° per year; so that she comes to the same node again, as from the line near A, Fig. 2, around to A again, in 19 days less than a year; or in 346 days. In just half this time, viz. 173 days, she passes her other node in the opposite side of the ecliptic, as at N. It follows, therefore, that at whatever time of the year we have eclipses at either node, we may be sure that in 173 days afterwards we shall have eclipses at the other node. And as for any given year eclipses commonly happen in two opposite months, as January and July, February and August, May and November, these opposite months, whichever they may be, are called for that year the *Node Months.*

5. There cannot be less than two nor more than seven

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* Olmsted.

eclipses in one year. If but two, they will both be of the sun; but if seven, five will be of the sun and two of the moon. The usual number is two solar and two lunar.

Lesson 89.

ECLIPSES, OR OCCULTATIONS OF THE STARS.

The occultation of a star is caused by the moon's passing between us and it, and concealing it from our view. Though a very simple and common phenomenon, it is, nevertheless, a very interesting one. At New Moon, especially, the star occulted may be traced to the very border of the moon's eastern limb, when it suddenly goes out. From these stellar occultations, or eclipses of the stars, many important conclusions may be drawn.

They teach us that the moon is an opaque body, terminated by a real and sharply defined surface, intercepting light like a solid.

They prove to us, that at those times when we cannot *see* the moon, she really exists, and pursues her course; and that when we see her only as a crescent, however narrow, the whole globular body *is there*, filling up the deficient outline, though unseen. For occultations take place indifferently at the dark and bright, the visible and invisible outline, whichever happens to be towards the direction in which the moon is moving; with this only difference, that a star *occulted* by the bright limb, if the phenomenon be watched with a telescope, gives notice, by its gradual approach to the visible edge, when to expect its disappearance; while, if occulted at the dark limb, if the moon, at least, be more than a few days old, it is, as it were, extinguished in mid-air, without notice or visible cause for its disappearance, which, as it happens *instantaneously*, and without the slightest previous diminution of its light, is always surprising; and, if the star be a large and bright one, even startling from its suddenness. The reappearance of a star, too, when the moon has passed over it, takes place, in those cases when the bright side of the moon is foremost, not at the concave outline of the crescent, but at the invisible outline of the complete circle, and is scarcely less surprising from its suddenness, than its disappearance in the other case.*

Lesson 90.

ECLIPSES OF JUPITER'S MOONS.

Every planet in the Solar System, whether primary or secondary, casts its shadow in the direction opposite to the sun. But none of the primaries can eclipse each other. In every case, however, where they are attended by satellites, there may be eclipses.

Of the *number*, *distances*, *magnitudes*; and *motions* of Jupiter's moons, we have already spoken in Lesson 81. It remains now to consider their *eclipses*.

From the magnitude of Jupiter, and his distance from the sun, it will be seen at once that he must cast a shadow of great dimensions, extending far into space towards the orbit of Saturn. But in order fully to understand the subject of his eclipses, it will be necessary to take into the account not only his distance, magnitude, &c., but the near coincidence of his *orbit* with the *ecliptic*, his *equator* with his *orbit*, and the *orbits* of his moons with his *equator*. All these points will be found duly noticed under their appropriate heads in the preceding lessons. Let it be remembered then—

1. That Jupiter casts a *broad* and *long* shadow in the direction opposite the sun.

2. That the centre of this shadow lies in the plane of his orbit, which differs only 1¼° from the plane of the ecliptic. (32.)

3. That his axis is inclined to his orbit only 3° 5′, and of course the plane of his equator nearly coincides with that of his orbit. (50.)

4. Three of his moons revolve very nearly in the plane of his equator, and must consequently pass near the centre of his shadow at every revolution. They must, therefore, be totally eclipsed.

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* Herschel's Astronomy

5. The most distant of his satellites has an orbit more inclined to the ecliptic, so that she sometimes but just grazes the border of the shadow in passing, and sometimes wholly escapes. But these instances are comparatively rare. As a general rule, it may be said that the satellites of Jupiter are *totally eclipsed* at *every revolution;* so that by determining the number of revolutions each makes in a month, (81,) and adding them together, we find the number of eclipses in that period of time. They amount to about forty.

6. From the *nearness* of his satellites (Lesson 81) we infer that they must pass his shadow where its diameter must be nearly as great as that of Jupiter; hence the eclipses are usually total, and last for some time.

7. The *shadows* of the satellites, being much longer than those of our moon, on account of their greater distance from the sun, and the nearness of the satellites to Jupiter, are cast upon *him* at every revolution. They may be seen with good telescopes " like small round ink spots" traversing his disc.

8. The *entrance* of Jupiter's moons into his shadow is called their *immersion;* and their egress therefrom their *emersion.* Tables have been constructed showing the *precise time* when these shall take place, for a given longitude on the earth, as, for instance, Greenwich Observatory; which tables are employed, in connection with a *chronometer* or accurate timepiece, for determining terrestrial longitude.

Lesson 91.

ECLIPSES OF SATURN AND HERSCHEL.

Of the satellites of these two planets, too little is known to admit of any very positive statements in respect to their eclipses. Indeed very little is said upon this subject, even by the ablest practical astronomers. Of Saturn it is remarked by Dr. Herschel, that owing to the obliquity of his rings, and of the orbits of his satellites to the ecliptic, they suffer no eclipses, the interior ones excepted, until near the time when the rings are seen *edgewise*. (See Lesson 66, and Map.)

Of the eclipses of Herschel's moons, nothing whatever is known by observation, and very little by theory, as deduced from their distances, inclination of orbits, &c.

CHAPTER V.

PHILOSOPHY OF THE TIDES.

Lesson 92.

NATURE AND CAUSES OF TIDES.

(Map **14.**)

THE alternate rising and falling of the waters of the ocean are called *Tides*. The rising of the waters is called *Flood* tide, and their falling *Ebb* tide. There are two flood and two ebb tides every day.

The *cause* of the tides is the attraction of the sun and moon upon the earth and the waters surrounding it.

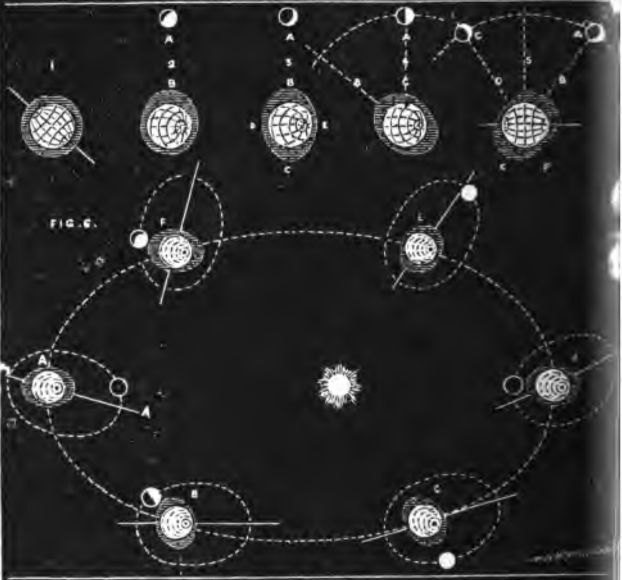
Fig. 1 represents the earth surrounded by water in a state of rest, or as it would be were it not acted upon by the sun and moon.

Fig. 2 shows the moon at a distance above the earth, and attracting the waters of the ocean so as to produce a high tide at B. But as the moon makes her apparent westward revolution around the earth but once a day, the simple raising of a flood tide on the side of the earth towards the moon, would give us but one flood and one ebb tide in twenty-four hours; whereas it is known that we have two of each.

Fig. 3, therefore, is a more correct representation of the tide-wave, as it actually exists, except that its height, as compared with the magnitude of the earth, is vastly too great. It is designedly exaggerated, to illustrate the *principle* under consideration. While the moon at A produces a high tide at B, we see a high tide at C, on the

MAP No. 14.

PHILOSOPHY OF TIDES.



THIS MAP ILLUSTRATES

THE GENERAL CHARACTER, NATURE & CAUSES OF TIDES. P. 120.
THE LAGGING OF THE TIDE-WAVE BEHIND THE MOON,
AND ALSO ITS EXCURSIONS IN LATITUDE. _ _ P. 122.
THE NATURE & CAUSES OF SPRING & NEAP TIDES. 123.
THE EFFECT OF THE VARIATIONS IN THE DISTANCES
OF THE SUN & MOON UPON THE TIDES. _ _ P. 127.
THE REVOLUTION OF THE APSIDES OF THE MOON'S ORBIT. 129.

opposite side of the earth. Of course it is low tide, at this time, at D and E; and as these four tides, viz. two high and two low, traverse the globe from east to west every day, it accounts for both the rising and falling of the tides every twelve hours.

But the most difficult point remains yet to be elucidated. "The tides," says Dr. Herschel, "are a subject on which many persons find a strange difficulty of conception. That the moon, by her attraction, should heap up the waters of the ocean under her, seems to most persons very natural. That the same cause should, at the same time, heap them up on the opposite side of the earth, [as at C, Fig. 3,] seems to many palpably absurd. Yet nothing is more true, nor indeed more evident, when we consider that it is not by her *whole* attraction, but by the *differences* of her attractions at the two surfaces and at the centre, that the waters are raised."*

The law of gravitation (17) is the same which prevails in the diffusion of light, (12,) namely, that *its force is inversely as the squares of the distances;* or, in other words, as the square of the distance is *diminished*, the force of attraction is *increased*, and *vice versa*. Let this rule be applied to the earth and moon, Fig. 3.

1. In the first place, nothing can be more evident than that the tide-water at B is the whole diameter of the earth, or 8,000 miles nearer the moon at A than the waters of the opposite side of the earth at C. They must also be 4,000 miles nearer than the *centre* of the earth, or the parts between D and E; while these parts, in turn, are 4,000 miles nearer than the waters at C.

2. Now as the force of the moon's attraction depends upon her *distance*, it must follow, in the second place, that the different parts of the earth will be *unequally attracted*. B will be attracted more than D E, and D E more than C.

3. This unequal attraction of the different parts of the earth's surface will tend to *separate* these parts. As B is more strongly attracted than the body of the earth, it

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* Treatise, 315.

will be drawn farther towards the moon, so as to produce a high tide on that side of the earth. The body, or solid parts of the earth, being nearer to the moon than the waters at C, will also recede from them towards the moon, causing the waters of the other side of the earth to tend from D E towards C, and raising a high tide at that point.

4. This perturbation, or swinging of the earth one way and the other, in her orbit, is assumed to be a constant result of the moon's attraction. Though the earth never deviates from her course more than the amount of her diameter, yet this is considered sufficient to account for the high tides opposite the moon, when in conjunction with the sun, upon the principles already explained. For a new theory of tides, see Lesson 94.

Lesson 93.

LAGGING OF THE TIDE—EXCURSIONS IN LATITUDE.

(Map **14.**)

1. The vertex, or highest point of the tide-wave, is generally about three hours behind the moon in her passage westward. This is illustrated at Fig. 4, where the moon is seen on the meridian at A, and the tide-wave hanging back to the east, with its vertex at B. The tide will be rising at C when the moon passes the meridian; and will continue to rise for three hours afterwards, when it will reach its highest point, and begin to ebb again.

The *cause* of this delay of the tide-wave is a want of time for the waters of the ocean to yield to the impulse given to them by the moon's attraction. Besides, as the moon continues to act upon the waters east of her meridian, for some time after she has passed over them, it is natural that they should still continue to rise.

2. Not only does the tide lag behind the moon, but the moon lags behind her hour, so to speak, or rises later and later every night, as she advances eastward *in her orbit;* so that high or low water is about fifty minutes

later every day, in reaching any particular meridian, than on the day preceding.

3. The position of the moon in regard to the *equinoctial* has also its effect in modifying the tides. This is illustrated at Fig. 5, where the moon is seen at A, *south* of the equinoctial, and the vertex of the tide-wave at B, on the Tropic of Capricorn. Of course the vertex of the opposite wave would be at E, in the *northern* hemisphere. Were the moon at C, or *north* of the equator, the vertices of the wave would be shifted from B and E to D and F. It is in this way that the *declination* of the sun and moon (47) materially affects the tides in any particular latitude. As the vertex of the tide-wave tends to place itself vertically under the luminary which produces it, when this vertical changes its point of incidence on the surface, the tide-wave must tend to shift accordingly; and thus, by monthly and annual periods, must tend to increase and diminish alternately the principal tides. The period of the moon's nodes is thus introduced into this subject; her excursions in declination in one part of that period being 29°, and in another only 17°, on either side of the equator.*

It is on this account, that in high latitudes every alternate tide is higher than the intermediate ones, the evening tides in summer exceeding the morning tides, and the morning tides in winter exceeding those of the evening.

Lesson 94.

SPRING AND NEAP TIDES.

(Map 14.)

1. We have hitherto spoken chiefly of the moon as instrumental in the production of the tides. But though she is the *principal*, she is not the *only* cause. The mass of the sun is seventy millions of times greater than that of the moon, (70,) but in consequence of his great *distance*,

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* Herschel's Treatise, 317, 318.

his influence upon the earth in the production of tides is only about *one-third* as great as that of the moon. Still it is amply sufficient to produce a perceptible tide-wave of itself, independently of the aid of the moon. Now as the solar and lunar influences are to each other as *one* to *three*, it is evident that when the two forces are combined they will produce tides *one-third higher* than usual; and when they counteract each other, the lunar tide-wave will prevail, but will be *one-third lower* than usual. These extraordinary variations are called the *Spring* and *Neap* tides. There are two of each every month. The spring, or highest tides, occur at the *syzygies*, or at new and full moon, and the neap tides at her *quadratures*.

A, B, C, F, Fig. 6, are intended to illustrate these phenomena. At A, the moon is seen *in conjunction*. It is now new moon, and the sun and moon act together upon the waters of the ocean, producing a *Spring tide*. The map shows the tide-wave as considerably higher than at F or B.

2. At B, the moon has passed to her *first quarter*, so that her attraction is in a direction at right angles with that of the sun. But as she exerts *three-fourths* of all the attractive force of the sun and moon both, she succeeds in producing a lunar tide *in spite of the sun*, though he subtracts one-third from what would otherwise be its elevation. On these principles we account for the *Neap tides*.

3. At C, the sun and moon are seen in *opposition*, and the earth exhibits *another spring tide*. But here it is evident that the tide-wave opposite to each luminary respectively, cannot be materially augmented by the perturbations of the body of the earth, as illustrated at Fig. 3, and explained at the beginning of this chapter: for as the sun and moon act in direct opposition to each other, they tend to keep the earth from swinging towards either. But as the moon exerts three times the force of the sun upon the earth, she will attract the earth towards her, in spite of the sun; so that she will thus contribute to the production of the tide-wave on the side of the earth towards C. On the hemisphere *towards* the moon, she must raise

her own tide, and that, too, with the whole force of the sun's attraction acting against her. How, then, is the spring tide produced at this time on the side of the earth opposite the sun ? And yet such is the fact.

Here is a point which it must be acknowledged is not satisfactorily explained by the prevailing theory of tides. When the sun and moon are in *opposition*, they must necessarily *diminish* that perturbation of the earth, which is assumed to be the cause of spring tides, and as the cause is reduced, the effect also should be reduced. According to this theory, therefore, we ought to have a *neap* instead of a *spring* tide, when the sun and moon are in opposition. The earth cannot swing in two opposite directions at the same time. Even Prof. Olmsted, whose abilities as an astronomer and mathematician are universally acknowledged, seems to be at a loss here. He says:—"At the time of new moon, the sun and moon both being on the same side of the earth, [as represented at A and D,] and acting upon it in the same line, their actions conspire, and the sun may be considered as adding so much to the force of the moon. We have already explained how the moon contributes to raise a tide on the opposite side of the earth. But the sun, as well as the moon, raises its own tide-wave, which, at new moon, coincides with the lunar wave. At full moon, also, the two luminaries conspire in the same way to raise the tide; for we must recollect, that each body contributes to raise the tide on the opposite side of the earth, as well as on the side nearest to it. At both the conjunctions and oppositions, therefore, that is, at the syzygies, we have unusually high tides."*

Here it will be seen that the learned author speaks of the *fact* of spring tide at full moon, and refers to the general principles upon which we account for spring tide at *new* moon; but *how* the sun and moon, acting in *opposition*, can produce spring tides, remains yet to be explained.

4. At F, we see the moon in the neighborhood of her

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* Introduction to Astronomy, 168.

last quarter, and the earth exhibiting the *neap tides* again. We have thus passed through with one lunation, in which we have at A and C, *two spring tides*, and at B and F *two* neap tides.

The spring tides are not at their height at the moment of the syzygies, but about thirty-six hours afterwards.

PROFESSOR DAVIES' THEORY.

Since the foregoing was in type, the author accidentally met with Prof. Davies, formerly of West Point, who in view of the exceptions we had taken to the prevailing philosophy, on the preceding page, submitted the following theory. So far as we can discover, it is a philosophical one, and it is certainly more satisfactory upon some points than the prevailing doctrine, which we had previously ventured to call in question. In the correctness of his theory, Prof. D. expresses entire confidence; and by his consent it is here inserted for the benefit of the reader.

The principle upon which he accounts for the tides, is that of *hydrostatic pressure*. When fluids of different specific gravity are mingled together, the heavier will displace the lighter, and cause them to rise to the surface. If the waters of the ocean were not acted upon by the sun or moon, their specific gravity would be the same all over the world; and they would consequently balance each other, producing equilibrium, as represented at Fig. 1. But the sun and moon do attract the waters of the ocean, and destroy their equilibrium. Take the earth and moon as represented at Fig. 3. While the moon is at A, the tendency of her attraction is to diminish the specific gravity or weight of the waters at B, as she overcomes a portion of the earth's gravitating force; so that these waters become *lighter* than they are wont to be. At the same time the moon acts upon the waters at D E with a slightly diminished force; but the tendency at these points is in a *horizontal* direction, or from D E towards A, and not away from the earth's centre. Of course, then, the specific gravity of the water is not *lessened* at D and E, but rather *increased*. But as the waters at B are rendered lighter by the moon's attraction, the waters at D E, having retained their usual weight, at least, will displace the former, thus causing the waters to fall at D and E, and rise at B and C. In a word, the difference in the *direction* of the moon's attraction at B and D E, as respects a perpendicular to the earth's centre, makes a difference in the *weight* of the waters at these two points; and the waters at D E, being *heaviest*, sink down till the lighter waters at B and C are increased enough in quantity to balance them; or till equilibrium is produced.

This theory applies as well to spring tides at full moon as to any other tides; and besides, it requires no sensible perturbations of the earth as the result of the moon's attraction. It is, therefore, preferable to the common theory laid down by authors, and is commended to the student as decidedly the best method of accounting for the production of Tides.

Lesson 95.

OTHER INEQUALITIES OF THE TIDES.

(Map 14.)

1. The tides vary in height, according to the *distances* of the earth and moon at the time when they occur. Take, for example, the spring tides at New Moon. If the earth is at her aphelion distance from the sun, and the moon in apogee, as we see represented at A, Fig. 6, the attraction of both the sun and moon will be less than their average amount, so that there will be but a *moderate* spring tide; but if the moon is in perigee, and the earth at her perihelion distance, as seen at D, both the sun and moon, being at their nearest points to the earth, and in conjunction, will exert their full attractive influence upon the earth; and the spring tide will be unusually high, as shown on the map.

2. At E the earth is near her perihelion, and the moon in opposition and in apogee. In such a case the

sun has his *greatest* agency in producing the tides and the moon her *least*. This will tend to equalize their forces, and only an ordinary spring tide will be produced.

3. The *height* of the tide-wave in different parts of the world is exceedingly various, owing to its being crowded into narrow channels in some instances, and to various other local causes. In open seas the spring tides are about eleven, and the neap tides about seven feet. At London the spring tides rise to the height of nineteen feet; at the mouth of the Indus, thirty feet; in the river Severn, England, forty feet; at St. Maloes, in France, forty-five feet; and at Cumberland, Bay of Fundy, seventy-one feet. This last is the highest tide in the world, and is caused by the meeting of the great northern and southern tide-waves of the Atlantic, which here come together in opposite directions.

The height of tides on different portions of the western continent has been given as follows:

Cumberland, Bay of Fundy, . . .	71	feet.
Boston, ...	11	"
New Haven, ...	8	"
New York, ...	5	"
Charleston, S. C., ...	6	"

This table seems to accord well with the theory just named, in regard to the *cause* of the excessively high tides in the Bay of Fundy.

4. The lagging of the tide-wave behind the moon (93) is greatly modified by local causes. Though the tides are usually highest about three hours after the moon has passed the meridian, it is often retarded by shoals and channels, and by striking against capes and headlands, so that, as exceptions to the general rule, high tides happen at all distances of the moon from the meridian.

5. Lakes and inland seas have no perceptible tides, in consequence of their inconsiderable magnitude, as compared with the waters of the ocean.

6. Dr. Herschel observes that the action of the sun

and moon produces *tides in the atmosphere,* as well as in the water; and that delicate observations have rendered them sensible and measurable. The pupil will find a remark concerning *tides on the sun,* in Chapter VII., where the various theories of the solar spots are considered.

Lesson 96.

MOTION OF THE APSIDES OF THE MOON'S ORBIT.

(Map **14.**)

At the close of Lesson 73, we promised in this chapter to speak of the motion or revolution of the moon's *apsides.* The *apsides* of the moon's orbit are her perihelion and aphelion points in her orbit; and the *line* of the apsides is a line drawn through those points, as shown in Fig. 6, wherever the moon's orbit is represented. At A this line is marked M A.

Now the *motion of the apsides* is the revolution of these points around the ecliptic from west to east. The map shows this revolution as we trace the moon around from A to F, in which place the line of the apsides, or the major axis of the ellipse, is at right angles with itself, as shown at A.

The apsides of the moon's orbit make a complete revolution in about nine years. In four and a half years the line A M will shift ends, so that the perihelion point M will be towards the sun; and in four and a half years more it will shift ends again, so that the moon will reach her perigee again at M, or in the same part of the heavens. In this way the apsides constantly advance eastward, till, at the end of *nine years,* they finish a complete revolution.

It will not be supposed, after what we have said above, that the apsides shift ends *suddenly,* or all at once. This is not the case. Their motion is gradual and uniform, as shown on the map.

As already stated in the chapter on Eclipses, the motion of the moon's apsides must always be taken into the account in predicting their occurrence, as well as in the explanation of the tides.

CHAPTER VI.

OF COMETS.

Lesson 97.

GENERAL DESCRIPTION OF COMETARY BODIES.

(Map **15.**)

1. Comets are the most singular class of bodies belonging to the Solar System. They derive their name from the Greek word *coma*, which signifies *bearded* or *hairy*.

2. A comet usually consists of three parts—the *Nucleus*, the *Envelope*, and the *Tail.* The *Nucleus* is what may be called the *body* or *head* of the comet, as seen at N, on the map. The *Envelope* is the nebulous or hairy covering that surrounds the nucleus. It may be seen around the nuclei of several of the specimens on the map, and especially that of 1585. The *Tail* of a comet is an expansion or elongation of the envelope.

3. Some comets have *no perceptible nucleus*, their entire structure being like that of a thin vapory cloud, passing rapidly through the heavens.

4. Many comets have simply the envelope, *without any tail* or elongation. Such were those that appeared in 1585 and 1763, the former of which will be found on the map.

5. Cassini describes the comet of 1682 as being *as round and as bright as Jupiter, without even an envelope.* But these are very rare exceptions to the general character of cometary bodies.

6. The tails of comets usually lie in a direction *opposite to the sun;* so that from perihelion to aphelion they *precede* their nuclei or heads; or in other words, comets

seem, after having passed their perihelion, to *back out* of the Solar System. See Map 2.

7. The comet of 1823 is said to have had *two tails*, one of which extended *towards* the sun. This comet may be seen on the map, with a portion of its orbit. The sun is supposed to be on the left, and the comet passing down towards its perihelion. Its nucleus and envelope are distinctly represented.

8. The tails of comets are usually *curved* more or less, being concave towards the region from whence they come. This is well shown in the comets of 1811, 1823, and 1680. That of 1689 is said to have been curved like a Turkish sabre, as shown on the map.

The *cause* of this curvature of the tails of comets is supposed to be a very rare ethereal substance, which pervades space, and offers a slight resistance to their progress. Of course it must be almost infinitely attenuated, as the comets themselves are a mere vapor, which could make no progress through the spaces of the heavens were they not very nearly a vacuum. They could no more pass a medium as dense as our atmosphere, than an ordinary cloud could pass through the waters of the sea.

9. Comets have been known to exhibit *several tails* at the same time. That of 1744, represented on the map, had no less than *six tails* spread out in the heavens like an enormous fan.

10. The tails of comets *do not continue of the same uniform length.* They *increase* both in length and breadth as they approach the sun, and *contract* as they recede from him, until they often nearly disappear before the comet gets out of sight.

11. Instances have occurred in which tails of comets have been *suddenly expanded* or *elongated* to a great distance. This is said to have been the case with the great comet of 1811.

12. Of the *physical nature* of comets little is known. That they are in general very *light* and *vapory* bodies is evident from the fact that stars have sometimes been seen even through their densest portions, and are generally visible through their tails; and from the little attractive

influence they exert upon the planets in causing perturbations. While Jupiter and Saturn often *retard* and delay comets for months in their periodic revolutions, comets have not power in turn to *hasten* the time of the planets for a single hour; showing conclusively that the relative masses of the comets and planets are almost infinitely disproportionate.

Such is the extreme lightness or tenuity of cometary bodies, that in all probability the entire mass of the largest of them, if condensed to a solid substance, would not amount to more than a few hundred pounds. Sir Isaac Newton was of opinion that if the tail of the largest comet was compressed within the space of a cubic inch, it would not then be as dense as atmospheric air! The comet of 1770 got entangled, by attraction, among the moons of Jupiter, on its way to the sun, and remained near them for *four months;* yet it did not sensibly affect Jupiter or his moons. In this way the *orbits* of comets are often entirely changed. That they are in themselves *opaque bodies,* and *shine only by reflection,* is evident from their sometimes exhibiting distinct *phases;* from their increased brightness as they approach the sun; and from the known difference in the properties of direct and reflected light. The idea that they are, in reality, "fiery bodies," is unquestionably erroneous.

Lesson 98.

MAGNITUDES, VELOCITIES, AND TEMPERATURE OF COMETS.

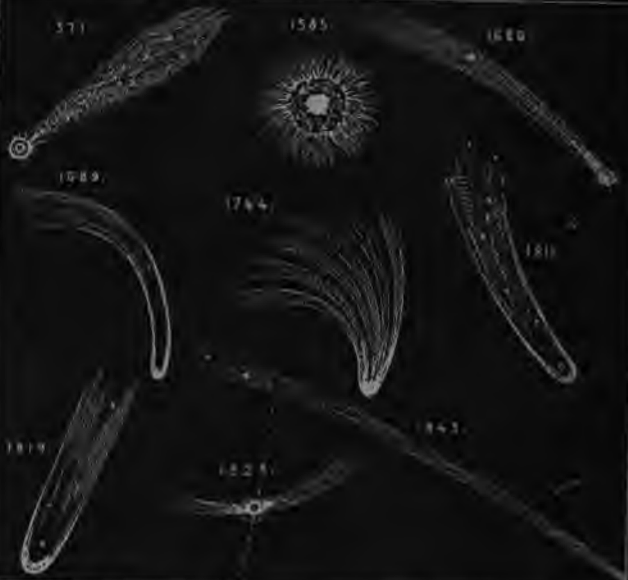
(Map 15.)

1. The HEADS or *nuclei* of comets are *comparatively small.* The following table shows the estimated diameter in five different instances.

The comet of	1778,	diameter of head	33	miles.
"	1805,	"	36	"
"	1799,	"	462	"
"	1807,	"	666	"
"	1811,	"	428	"

MAP No. 15.

VIEWS OF REMARKABLE COMETS.



THIS MAP ILLUSTRATES

THE GENERAL APPEARANCE, STRUCTURE & NATURE OF COMETARY BODIES. . . . . P. 130.

THE PARTICULAR APPEARANCE OF SOME OF THE MOST REMARKABLE COMETS, FROM B.C. 371, TO A.D. 1843 · 130. 132

THE ENORMOUS LENGTH OF THE TAILS OF COMETS, AS COMPARED WITH THEIR NUCLEI OR HEADS . P. 132-3

2. The TAILS of comets are often of enormous length and magnitude. That of 371 before Christ was 60° long, covering one third of the visible heavens. In 1618, a comet appeared which was 104° in length. Its tail had not all risen when its head reached the middle of the heavens. That of 1680 (see map) had a tail 70° long, so that though its head set soon after sundown, its tail continued visible all night.

The following table will show the length of the tails of some of the most remarkable comets, both in degrees and in miles. They will be characterized only by the year when they appeared.

B. C.	371,	60° - -	140,000,000 miles.
A. D.	1456,	60 - -	70,000,000 "
"	1618,	104 - -	65,000,000 "
"	1680,	70 - -	123,000,000 "
"	1689,	68 - -	100,000,000 "
"	1744,	30 - -	35,000,000 "
"	1769,	90 - -	48,000,000 "
"	1811,	23 - -	132,000,000 "
"	1843,	60 - -	130,000,000 "

As these estimates are the angles under which the comets were viewed *from the earth*, the length of their tails in miles would not be proportional to the angle merely, as their *distances* must also be taken into the account. So the comet of 1843, with an angular length of only 60° was longer in fact by 65,000,000 miles than the comet of 1618, with an angular length of 104°. At the time of measurement the latter was much nearer to the earth than the former when his dimensions were estimated.

The pupil should look up the comets named in the above table, so far as laid down on the map.

3. The VELOCITY with which comets often move, is truly wonderful. Their motions are accelerated as they approach, and retarded as they recede from the sun; so that their velocity is greatest while passing their perihelions. The comet of 1472 described an arc of the heavens of 120° in extent in a single day! That of

1680 moved, when near its perihelion, at the rate of 1,000,000 miles per hour.

4. The TEMPERATURE of some comets, when nearest the sun, must be very great. That of 1680 came within 130,000 miles of the sun's surface, and must have received 28,000 times the light and heat which the earth receives from the sun—a heat more than 2,000 times greater than that of red-hot iron! What substance can a comet be composed of to endure the extremes of heat and cold to which it is subject? Some have supposed that their tails were caused by the sun's light and heat rarefying and driving back the vapory substance composing the envelope.

Lesson 99.

PERIODS, DISTANCES, AND NUMBER OF COMETS.

(Map **15.**)

1. The PERIODS of but few comets are known. That of 1818, called "*Encke's Comet,*" has a period of only 3¼ years. *Biela's Comet* has a period of 6¾ years. That of 1682 (then first noticed with care, and identified as the same that had appeared in 1456, 1531, and 1607) has a period of about 76 years. It is called *Halley's* Comet, after Dr. Halley, who determined its periodic time.

The great comet of 1680 has a periodic time of 570 years, so that its next return to our system will be in the year 2,250. Many are supposed to have periods of thousands of years, and some have their orbits so modified by the attraction of the planets as to pass off in parabolic curves, to return to our system no more.

Prof. Nichol is of opinion that the greater number visit our system but once, and then fly off in nearly straight lines till they pass the centre of attraction between the Solar System and the Fixed Stars, and go to revolve around other suns in the far distant heavens.* Sir John Herschel expresses the same sentiment.†

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* Solar System, p. 135. † Treatise, American Ed. p. 289.

2. The DISTANCES to which those comets that return must go, to be so long absent, must be very great. Still their bounds are set by the great law of attraction, for were they to pass the point "where gravitation turns the other way," they would never return. But some, at least, *do* return, after their "long travel of a thousand years." What a sublime conception this affords us of the almost infinite space between the Solar System and the Fixed Stars!

The *perihelion distances* of the various comets that have appeared, and whose elements have been estimated by astronomers, are also exceedingly variable. While some pass very near the sun, others are at an immense distance from him, even at their perihelion. Of 137 that have been particularly noticed,

30 passed between the Sun and the orbit of Mercury;
44 between the orbits of Mercury and Venus;
34 " " " Venus and the Earth;
23 " " " the Earth and Mars;
6 " " " Mars and Jupiter.

3. The NUMBER of comets belonging to, or that visit, the Solar System is very great. Some have estimated them at several millions. When we consider that most comets are seen only through telescopes—an instrument of comparatively modern date—and that notwithstanding this some 450 are mentioned in ancient annals and chronicles, as having been seen with the naked eye, it is probable that the above opinion is by no means extravagant. It is supposed that not less than 700 have been seen at different times since the birth of Christ. The paths of only about 140 have been determined.

The extreme difficulty of observing comets whose nearest point is beyond the orbit of Mars, is supposed to account for the comparatively small number that have been seen without that limit; and the proximate uniformity of the distribution of their orbits over the space included within the orbit of Mars, seems to justify the conclusion, that though seldom detected beyond his path, they are nevertheless equally distributed through all the spaces of the solar heavens. Reasoning upon this hypothesis, Prof. Arago concludes that there are probably *seven millions* of comets that belong to or visit the Solar System.*

Lesson 100.

DIRECTION, ORBITS, AND NATURE OF COMETS.

(Map 15.)

1. The DIRECTION of comets is as variable as their forms or magnitudes. They enter the Solar System from all points of the heavens. Some seem to come up from the immeasurable depths below the ecliptic, and, having doubled "heaven's mighty cape," again plunge downward with their fiery trains, and are lost for ages in the ethereal void. Others appear to come down from the zenith of the universe, and having doubled their perihelion, reascend far above all human vision. Others again are dashing through the Solar System, in all possible directions, apparently without any prescribed path, or any guide to direct them in their eccentric wanderings. Instead of revolving uniformly from east to west, like the planets, their motions are direct, retrograde, and in every conceivable direction.

2. It is remarked by a late writer,† that the average *inclinations* of all the planes in which the comets now on record have been found to move, is about 90°. This he regards as a wonderful instance of the goodness of Providence, in causing their motions to be performed in a manner least likely to come in contact with the earth and the other planets.

3. The form of the comets' orbits is generally that of an ellipse greatly flattened or elongated. The sun being near one end of the ellipse, and the planets comparatively in his immediate neighborhood, the comets are in the vicinity of the sun and planets but for a short time, and

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* Arago and Lardner's Astronomy, p. 70.

† Prof. Kendall of Philadelphia.

then hasten outward again, beyond the limits of human vision, even with the aid of the best telescopes, to be gone even for centuries!

4. Comets were formerly regarded as harbingers of famine, pestilence, war, and other dire calamities. In one or two instances they have excited serious apprehension that the day of judgment was at hand; and that they were the appointed messengers of Divine wrath, hasting apace to burn up the world. It may be well, therefore, to devote a paragraph to the question, *Are comets dangerous in the Solar System?* That they are not, will be evident when we consider,

First, that there is scarcely the remotest probability of a *collision* between the earth and a comet. It has been determined, upon mathematical principles, and after the most extended and laborious calculation, that of 281,000,000 of chances there is only *one* unfavorable, or that can produce a collision between the two bodies. The risk, therefore, to which the earth is exposed of being struck by a comet, is like the chance one would have in a lottery, where there were 281,000,000 black balls and but one white one; and where the white ball must be produced at the first drawing to secure a prize.

In the second place, if a comet were to come in direct collision with the earth, it is not probable that it would be able even to penetrate our atmosphere; much less to dash the world in pieces. Prof. Olmsted remarks, that in such an event not a particle of the comet would reach the earth—that the portions encountered by her would be arrested by the atmosphere, and probably inflamed; and that they would perhaps exhibit on a more magnificent scale than was ever before observed, the phenomena of shooting stars, or meteoric showers.* The idea, therefore, that comets are dangerous visitants to our system has more support from superstition than from reason or science.

I cannot better conclude this chapter than in the language of the lamented Burritt: "What regions these bodies visit, when they pass beyond the limits of our view; upon what errands they come, when they again revisit the central parts of our system; what is the difference between their physical constitution and that of the sun and planets; and what important ends they are destined to accomplish in the economy of the universe, are inquiries which naturally arise in the mind, but which surpass the limited powers of the human understanding at present to determine."

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* Introduction to Astronomy, p. 274.

CHAPTER VII.

OF THE SUN.

Lesson 101.

GENERAL REMARKS RESPECTING THE SUN—ITS MAGNITUDE, ETC.

(Map 4.)

Although it has been found necessary to give many interesting facts respecting the sun, in the preceding lessons, it is thought important to repeat them here, with others, in a more systematic order; and with opportunity for descriptions and explanations more in detail.

Of all the celestial objects with which we are acquainted, none make so strong and universal an impression upon our globe as does the *Sun*. He is the great centre of the Solar System—a vast and fiery orb, kindled by the Almighty on the morn of creation, to cheer the dark abyss, and to pour his radiance upon surrounding worlds. Compared with him, all the solar bodies are of inconsiderable dimensions; and without him, they are wrapped in the pall of interminable night.

The sun is 886,000 miles in diameter. Were a tunnel opened through his centre, and a railway laid down, it would require, at the rate of thirty miles per hour, nearly three and a half years for a train of cars to pass through it. To traverse the whole *circumference* of the sun, at the same speed, would require nearly eleven years. His diameter is 112 times that of the earth, and his mass 1,400,000 times as great. He is 500 times larger than all the rest of the Solar System put together. The mean diameter of the moon's orbit is 480,000 miles; and yet were the sun to take the place of the earth, he would fill the entire orbit of the moon, and extend more than 200,000 miles beyond it on every side.

The *form* of the sun is that of a *spheroid;* his equatorial being somewhat greater than his polar diameter. The map referred to exhibits the relative diameters of the sun and planets.

Lesson 102.

SPOTS ON THE SUN—THEIR NUMBER.

(Map 4.)

By the aid of telescopes a variety of *spots* are often discovered upon the sun's disc. Their *number* is exceedingly variable at different times. From 1611 to 1629, a period of 18 years, the sun was never found clear of spots, except for a few days in December, 1624. At other times twenty or thirty were frequently seen at once; and at one period, in 1825, upwards of fifty were to be seen. Prof. Olmsted states that over one hundred are sometimes visible. From 1650 to 1670, a period of 20 years, scarcely any spots were visible; and for eight years, from 1676 to 1684, no spots whatever were to be seen. For the last 46 years, a greater or less number of spots have been visible every year. For several days, during the latter part of September, 1846, we could count sixteen of these spots which were distinctly visible, and most of them well defined; but on the 7th of October following, only six small spots were visible, though the same telescope was used, and circumstances were equally favorable.

Lesson 103.

NATURE OF THE SOLAR SPOTS.

(Map 4.)

The appearance of the solar spots is that of a dark *nucleus* surrounded by a border less deeply shaded, called a *penumbra*. They are both well represented on the map.

When seen through a telescope, the sun presents the appearance of a vast globe, wrapped in an ocean of flame, with the spots, like incombustible islands, floating in the fiery abyss. The principal facts by which we are to judge of their *nature* and *causes*, are the following:

1. The sun is often *entirely destitute* of spots.

2. When they are to be seen, the same spots do not regularly reappear on the east, and pass around, with every successive revolution, to the west.

3. They are exceedingly variable as to *number* and *magnitude*.

4. They have been known to *break into pieces*, and divide, and even finally to *disappear* altogether in a very short time.

5. They sometimes *break out* again in the same places; and new ones often break out where none were perceptible before.

6. When they disappear, the central dark spot always contracts into a point, and vanishes before the penumbra or border disappears.

7. In the neighborhood of the large spots, the surface of the sun is covered with strongly-marked streaks or arms, more luminous than the rest, called *faculæ*, among which the spots often break out. The dark spots are sometimes called *maculæ*.

8. The spots are all found within 30° of the sun's equator, or in a zone of 60° in width.

9. In a series of experiments conducted by Prof. Henry, of Princeton, by means of a thermo-electrical

apparatus, applied to an image of the sun thrown on a screen from a dark room, it was found that the spots were perceptibly colder than the surrounding light surface.

Concerning these wonderful spots a variety of opinions have prevailed and many curious theories have been constructed. Lalande, as cited by Herschel, suggests that they are the tops of mountains on the sun's surface, laid bare by fluctuations in his luminous atmosphere; and that the penumbræ are the shoaling declivities of the mountains, where the luminous fluid is less deep. Another gentleman, of some astronomical knowledge, supposes that the tops of the solar mountains are exposed by *tides* in the sun's atmosphere, produced by planetary attraction.

To the theory of Lalande, Dr. Herschel objects that it is contradicted by the sharp termination of both the internal and external edges of the penumbræ; and advances as a more probable theory, that "they are the dark, or at least comparatively dark, solid body of the sun itself, laid bare to our view by those immense fluctuations in the luminous regions of the atmosphere, to which it appears to be subject." Prof. Olmsted supports this theory by demonstrating that the spots must be "nearly or quite in contact with the body of the sun."

In 1773, Prof. Wilson, of the University of Glasgow, ascertained by a series of observations that the spots were probably "*vast excavations* in the luminous matter of the sun;" the nuclei being their bottom, and the umbræ their shelving sides.* This conclusion varies but little from that of Dr. Herschel, subsequently arrived at.†

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* A valuable paper upon the subject of the solar spots, written by the lamented Ebenezer Porter Mason, may be found in his excellent Memoir, by Prof. Olmsted, page 238.

† Nichol's Solar System, pp. 122–126.

Lesson 104.

MAGNITUDE OF THE SOLAR SPOTS.

(Map 4.)

The *magnitude* of the solar spots is as variable as their number. Upon this point the map will give a correct idea; as it is a pretty accurate representation of the sun's disc as seen by the writer on the 22d of September, 1846. In 1799, Dr. Herschel observed a spot nearly 30,000 miles in breadth; and he further states, that others have been observed whose diameter was upwards of 45,000 miles. Dr. Dick observes that he has several times seen spots which were not less that $\frac{1}{25}$ of the sun's diameter, or 22,192 miles across.

It is stated, upon good authority, that solar spots have been seen by the naked eye—a fact, from which Dr. Dick concludes that such spots could not be less than 50,000 miles in diameter. The observations of the writer, as above referred to, and represented on the map, would go to confirm this deduction, and to assign a still greater magnitude to some of these curious and interesting phenomena.

Lesson 105.

REVOLUTION OF THE SUN UPON HIS AXIS.

(Map 4.)

The axis of the sun is inclined to the ecliptic $7\frac{1}{2}^{\circ}$, or more accurately $7^{\circ}\ 20'$. This is but a slight deviation from what we may call a perpendicular, so that in relation to the earth, he may be considered as standing up and revolving with one of his poles resting upon a point just half his diameter below the ecliptic. The *proof* of his revolution is the same as that by which we determine the revolution of the planets, namely, the passage of spots over his disc. He revolves in the same direction in which the planets revolve around him, and the time occupied in making a complete sidereal revolution is 25 days 10 hours. But when a particular spot has arrived opposite any particular star from which it started, in the direction of which the earth was 25 days and 10 hours before, the earth is found to have advanced some 24°, or 1,700,000 miles in her orbit; and the sun must actually turn a little more than once round, to appear to make a complete revolution to a beholder on the earth. His *synodic* revolution consequently requires 27 days 7½ hours, or near 46 hours more time than his sidereal revolution.

Lesson 106.

DIRECTION, MOTIONS, AND PHASES OF THE SOLAR SPOTS.

(Map 4.)

As the result of the sun's motion upon his axis, his spots always appear first on his eastern limb, and pass off or disappear on the west. But though the direction of the spots, as viewed from the earth, is from east to west, it only proves his motion to coincide with that of the earth, which we call from west to east; as when two spheres revolve in the *same* direction, the sides towards each other will appear to move in *opposite* directions. During one half of the passage of the spots across the sun's disc, their apparent motion is *accelerated;* and during the remainder it is *retarded.*

This apparent irregularity in the motion of the spots upon the sun's surface, is the necessary result of an equable motion upon the surface of a globe or sphere. When near the eastern limb, the spots are coming partly towards us, and their angular motion is but slight; but when near the centre, their angular and real motions are equal. So, also, as the spots pass on to the west, it is their angular motion only that is diminished, while the motion of the sun upon his axis is perfectly uniform.

The figure of the sun affects not only the apparent *velocity* of the spots, but also their *forms.* When first seen on the east they appear narrow and slender, as represented on the left of Fig. 1. As they advance westward, they continue to widen or enlarge till they reach the centre, where they appear largest, when they again begin to contract, and are constantly diminished till they disappear.

Another result of the revolution of the sun upon an axis inclined to the ecliptic, and the revolution of the earth around him, is, that when viewed from our moveable observatory, the earth, at different seasons of the year, the *direction* of the spots seems materially to vary. This fact is illustrated by Fig. 2. In June we have, so to speak, a side view of the sun, his pole being inclined to the *left*. Of course, then, as he revolves, his spots will appear to ascend in a straight line. In September we have passed around in our orbit, to a point opposite the south pole of the sun, and the spots seem to curve upward. In December we have another side view of the sun, but we are opposite the point from which we had our first view, and on the other side of the ecliptic. The result is, that the poles of the sun are now inclined to the *right;* and the spots, in passing over his disc, incline downward. In March, we reach a point opposite the *south* pole of the sun, and the spots in revolving seem to curve downward. The polar inclination of the sun, as given in the figure, is greater than it actually is in nature, (see Lesson 49 and Map 8;) the present design being merely to illustrate the *principle* upon which we account for the peculiar motion of the solar spots.

Lesson 107.

PHYSICAL CONSTITUTION OF THE SUN.

Concerning the physical nature of the sun, very little is known. As before said, it appears, when seen through a telescope, like a globe of fire, in a state of violent commotion or ebullition. La Place believed it to be in a state of actual combustion, the spots being immense caverns or craters, caused by eruptions or explosions of elastic fluids in the interior.

The most probable opinion is, that the body of the sun is opaque, like one of the planets; that it is surrounded by an atmosphere of considerable depth; and that the light is sent off from a luminous stratum of clouds, floating above or outside the atmosphere. This theory accords best with his density, and with the phenomena of the solar spots.

Of the *temperature* of the sun's surface, Dr. Herschel thinks that it must exceed that produced in furnaces, or even by chemical or galvanic processes. By the law relative to the diffusion of light (Lesson 12) he shows that a body at the sun's surface must receive 300,000 times the light and heat of our globe; and adds that a far less quantity of solar light is sufficient, when collected in the focus of a burning-glass, to dissipate gold and platina into vapor.

The same writer observes that the most vivid flames disappear, and the most intensely ignited solids appear only as black spots on the disc of the sun, when held between him and the eye. From this circumstance he infers that however dark the body of the sun may appear, when seen through its spots, it *may*, nevertheless, be in a state of most intense ignition. It does not, however, follow of necessity that it *must* be so. The contrary is at least physically possible. A *perfectly reflective* canopy would effectually defend it from the radiation of the luminous regions above its atmosphere, and no heat would be conducted downward through a gaseous medium increasing rapidly in density.

The great mystery, however, is to conceive how so enormous a conflagration (if such it be) can be kept up from age to age. Every discovery in chemical science here leaves us completely at a loss, or rather seems to remove farther from us the prospect of explanation. If conjecture might be hazarded, we should look rather to the known possibility of an indefinite generation of heat by friction, or to its excitement by the electric discharge, than to any actual combustion of ponderable fluid, whether solid or gaseous, for the origin of the solar radiation.*

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* Herschel's Treatise on Astronomy.

Lesson 108.

THE ZODIACAL LIGHT.

The *Zodiacal Light* is a faint nebulous light, resembling the tail of a comet, or the milky-way, which seems to be reflected from the regions about the sun; and is distinguishable from ordinary twilight. Its form is that of a pyramid or cone, with its base towards the sun, and inclined slightly to the ecliptic. It seems to surround the sun on all sides, though at various depths, as it may be seen in the morning preceding the sun, as well as in the evening following him; and the bases of the cones where they meet at the sun, are much larger than his diameter.

The *form* of this substance surrounding the sun, and which is sufficiently dense to reflect his light to the earth, seems to be that of a *lens;* or rather that of a huge wheel, thickest at the centre, and thinned down to an edge at the outer extremities. Its being seen edgewise, and only one-half at a time, gives it the appearance of two pyramids with their bases joined at the sun.

Of the *nature* of this singular phenomenon very little is positively known. It was formerly thought to be the atmosphere of the sun. Prof. Nichol says:—Of this at least we are certain—the Zodiacal Light is a phenomenon precisely similar in kind to the nebulous atmospheres of the distant stars, &c. Sir John Herschel remarks, that it is manifestly of the nature of a thin lenticularly-formed atmosphere, surrounding the sun, and extending at least beyond the orbit of Mercury, and even of Venus. He gives the apparent angular distance of its vertex from the sun, at from 40° to 90°; and the breadth of its base from 8° to 30°. It sometimes extends 50° westward, and 70° east of the sun at the same time.

In regard to its atmospheric character, Dr. Dick observes, that this opinion now appears extremely dubious; and Prof. Olmsted refers to La Place, as showing that the solar atmosphere could never reach so far from the sun as this light is seen to extend.

Another class of astronomers suppose this light, or rather the substance reflecting this light, to be some of the original matter of which the sun and planets were composed—a thin nebulous substance in a state of condensation, and destined either to be consolidated into new planetary worlds, during the lapse of coming ages, or to settle down upon the sun himself as a part of his legitimate substance. This theory will be noticed again when we come to speak of Nebulæ and Nebulous Stars, in the second part of this work.

Prof. Olmsted supposes the Zodiacal Light to be a nebulous body, or a thin vapory mass revolving around the sun; and that the *Meteoric Showers*, which have occurred for several years, in the month of November, may be derived from this body. This is the opinion of Arago, Biot, and others.

The best time for observing the Zodiacal Light is on clear evenings, in the months of March and April. It may be seen, however, in October, November, and December, before sunrise; and also in the evening sky.

It is an interesting fact, stated by Prof. Nichol, that this light, or nebulous body, lies in the plane of the sun's equator. A line drawn through its transverse diameter, or from one apex of the pyramids to the other, would cross the axis of the sun at right angles. This fact would seem to indicate a revolution of this curious substance with the sun upon his axis.

But, as already stated, the subject of the Zodiacal Light is in an unsettled state. After considering the various facts and theories stated, the learner must wait till future observations and discoveries shall furnish something upon this point more definite and satisfactory.

Lesson 109.

MOTION OF THE SUN IN SPACE.

Although in general terms we speak of the sun as the fixed centre of the Solar System, still the sublime and astonishing fact has been ascertained, that the sun, and the whole Solar System, *have an actual motion in space.* Indeed the sun may be said to have three distinct motions.

1. It has a revolution upon its own axis, once in 25 days 9½ hours, as described in Lesson 105.

2. "It has a periodical motion, in nearly a circular direction, around the common centre of all the planetary motions; never deviating from its position by more than twice its diameter." From the known laws of gravitation, it is certain that the sun is affected in some measure by the attraction of the planets, especially when many of them are found on the same side of the ecliptic at the same time; but this would by no means account for so great a periodical motion.

3. It is found to be moving, with all its retinue of worlds, in a *vast orbit,* around some distant and unknown centre. This opinion was first advanced, we think, by Sir William Herschel; but the honor of actually determining this interesting fact belongs to Struve, who ascertained not only the *direction* of the sun and Solar System, but also their *velocity.* The point of tendency is towards the constellation of stars called Hercules, Right Ascension 259°, Declination 35°. See Lessons 47, 48. The *velocity* of the sun, &c., in space, is estimated at about 28,000 miles per hour, or nearly 8 miles per second!

With this wonderful fact in view, we may no longer consider the sun as fixed and stationary, but rather as a vast and luminous *planet,* sustaining the same relation to some central orb, that the primary planets sustain to him, or that the secondaries sustain to their primaries. Nor is it necessary that the stupendous mechanism of nature should be restricted even to these sublime proportions. The sun's central body may also have its orbit, and its centre of attraction and motion, and so on, till, as Dr. Dick observes, we come to the great centre of all—to the THRONE OF GOD.

Since the above was written an article has appeared in several European journals, announcing the probable discovery of the sun's *central orb;* the *inclination of his orbit to the plane of the ecliptic;* and his *periodic time!*

As it contains several interesting calculations, and is otherwise a remarkable paper, it is here copied for the benefit of the student.

THE CENTRAL SUN.

At the close of the meeting of the Royal Irish Academy, on the 14th of December, [1846,] Sir William Hamilton announced that he had just received from Professor Mädler, of Dorpat, the extraordinary and exciting intelligence of the presumed discovery of a central sun!

By an extensive and laborious comparison of the quantities and directions of the proper motions of the stars in various parts of the heavens, combined with indications afforded by the parallaxes hitherto determined, and with the theory of universal gravitation, Professor Mädler has arrived at the conclusion that the Pleiades form the central group of our whole astral or sidereal system, including the Milky Way and all the brighter stars, but exclusive of the more distant nebulæ, and of the stars of which those nebulæ may be composed. And within this central group itself he has been led to fix on the star Alcyone, (otherwise known by the name of ε Tauri,) as occupying exactly or nearly the position of the centre of gravity, and as entitled to be called the central sun.

Assuming Bessel's parallax of the star 61 Cygni, long since remarkable for its large proper motion, to be correctly determined, Mädler proceeds to form a first approximate estimate of the distance of this central body from the planetary or solar system; and arrives at the (provisional) conclusion, that Alcyone is about thirty-four million times as far removed from us, or from our own sun, as the latter luminary is from us. It would, therefore, according to this estimation, be at least a million times as distant as the new planet, of which the theoretical or deductive discovery has been so great and beautiful a triumph of modern astronomy, and so striking a confirmation of the law of Newton. The same approximate determination of distance conducts to the result, that the light of the central sun occupies more than five centuries in travelling thence to us.

The enormous orbit which our own sun, with the earth and the other planets, is thus inferred to be describing about that distant centre—not indeed under its influence alone, but by the combined attractions of all the stars which are nearer to it than we are, and which are estimated to amount to more than one hundred and seventeen millions of masses, each equal to the total mass of our own Solar System—is supposed to require upwards of *eighteen millions of years* for its complete description, at the rate of about eight geographical miles in every second of time.

The plane of this vast orbit of the sun is judged to have an inclination of about eighty-four degrees to the ecliptic, or to the place of the annual orbit of the earth; and the longitude of the ascending node of the former orbit on the latter is concluded to be nearly two hundred and thirty-seven degrees.

CHAPTER VIII.

MISCELLANEOUS REMARKS UPON THE SOLAR SYSTEM.

Lesson 110.

NEBULAR THEORY OF THE ORIGIN OF THE SOLAR SYSTEM.

It was the opinion of La Place, a celebrated French astronomer, that the entire matter of the Solar System, which is now mostly found in a consolidated state, in the sun and planets, was once a vast *nebula*, or gaseous vapor, extending beyond the orbits of the most distant planets—that in the process of gradual condensation, by attraction, a *rotary motion* was engendered and imparted to the whole mass—that this motion caused the consolidating matter to assume the form of various concentric *rings*, like those of Saturn; and, finally, that these rings, collapsing, at their respective distances, and still retaining their motion, were gathered up into *planets*, as they are now found to exist. This opinion is supposed to be favored, not only by the fact of Saturn's revolving rings, but by the existence of the Zodiacal Light, or a resisting medium about the sun, (108,) and also by the character of irresolvable or planetary nebulæ, hereafter to be described.

On the other hand, the nebular theory is open to many plausible, if not insurmountable objections.

1. It seems to be directly at variance with the Mosaic account of the creation of the sun, moon, and stars. The idea that the sun and all the planets were *made up*, so to speak, out of the same general mass, not only throws the *creation* of this matter back indefinitely into eternity, but it substitutes the general law of attraction for the more direct agency of the Almighty. The creation spoken of in the Bible thus becomes, not the *originating* of things that did not previously exist, but the mere *organization*, or *arrangement* of matter already existing. And as attraction—the supposed agency in this arrangement—is still in operation, the creation of all things is resolved into an ordinary, we might almost say, an everyday occurrence.

2. The supposed consolidation of the nebulous mass, in obedience to the general law of attraction, does not of itself account for the *rotary motion* which is an essential part of the theory. Under the influence of mere attraction, the particles must tend directly towards the centre of the mass, and consequently could have no tendency to produce a rotary motion during the process of condensation.

3. The variation of the planetary orbits from the plane of the sun's equator, contradicts the Nebular theory. If the several primary planets were successively thrown off from the general mass, of which the sun is a part, they could not have been separated from the parent body, till they were near the plane of its equator. Now, as the sun is assumed to be a part of the same mass, revolving still, the theory would require that the portions now separated from him and called

planets, should still revolve in the plane of his equator. But instead of this being a fact, it is found that some of them vary from this plane to the amount of near 42°. See Lessons 32 and 105, and the maps.

4. This theory assumes not only that the primary planets were thrown off from the parent mass by its rapid revolution, but that the primaries in turn threw off their secondary planets or satellites. These of course, then, should all revolve in the plane of the planetary equators respectively, and in the direction in which their primaries revolve. But their orbits not only depart from the plane of the equators of their primaries, Jupiter's satellites excepted, (Lessons 70, 81, 82, 83,) but the moons of Herschel actually have a *retrograde* or *backward revolution*. See 83.

5. If the sun and planets are composed of what was originally the same mass, it will be necessary to show why they differ so materially in their physical nature—why the sun is self-luminous and the planets opaque, &c.

But we have not room to discuss the subject at length in this treatise. It is but justice, however, to say, that men eminent for learning and piety have advocated what is called the *Nebular Theory,* in the belief that it was perfectly consistent with the Mosaic account of the creation of the heavens and the earth. If the opinion of the writer is desired, he is frank to state, that while he acknowledges the force of some of the considerations urged in its support, he has not yet seen reason for adopting this thory of the formation of the Solar System.

Lesson 111.

LAWS OF PLANETARY MOTION.

(Map 7.)

There are three general principles which govern the motions of all the planets. These were first discovered by *Kepler,* a German astronomer, from whom they have since been called *Kepler's laws.* They are as follows:

1. *The orbits of the Earth, and all the Planets, are* ELLIPSES, *having the Sun in the common focus.*

"The ellipse is a curve, of an oval or elongated form, all the points of which lie in the same plane. The largest diameter of an ellipse is called the *major,* or *transverse axis.* It divides the curve into two equal parts. The *foci* are two points in the transverse axis, equally distant from the centre. If from any point of the curve two lines be drawn to the two foci, their sum will be equal to the transverse axis. Since the sun is in one of the foci of the elliptical orbit of a planet, the latter will, at different times, be at unequal distances from the sun." At whatever point in its orbit a planet may be, a line drawn from its centre to the centre of the sun, is called the *radius vector.*

2. *The radius vector, (or line drawn from the centre of the Sun to the centre of any Planet revolving around it,) describes equal areas in equal times.*

The nearer a planet is to the sun, the more rapid its motion, (19.) It follows, therefore, that if the orbit of a planet is an ellipse, with the sun in one of the foci, its rate of motion will be unequal in different parts of its orbit,—swiftest at perihelion, and slowest at aphelion. From perihelion to aphelion, the centripetal more directly counteracts the centrifugal force, (20,) and the planet is *retarded.* On the other hand, from the aphelion to the perihelion point, the centripetal and centrifugal forces are united, or act in a similar direction. They consequently hasten the planet onward, and its rate of motion is constantly *accelerated.*

Now suppose when the planet is at a certain point near its perihelion, we draw a line from its centre to the centre of the sun. This line is the *radius vector.* At the end of one day, for instance, after the planet has advanced considerably in its orbit, we draw another line in the same manner to the sun's centre, and estimate the area between the two lines. At another time when the planet is near its aphelion, we note the space over which the radius vector travels in one day, and estimate its area. On comparison it will be found, that notwithstanding the unequal *velocity* of the planet, and consequently of the radius vector, at the two ends of the ellipse, the *area* over which the radius vector has travelled is the same in both cases. The same principle obtains in every part of the planetary orbits, whatever may be their ellipticity or the mean distance of the planet from the sun; hence the rule, that *the radius vector describes equal areas in equal times.**

3. *The squares of the periodic times are as the cubes of the mean distances from the Sun.*

"Take, for example, the earth and Mars, whose periods are 365.2564 and 686.9796 days, and whose distances from the sun are in the proportion of 1 to 1.52369; and it will be found that

$$(365.2564)^2 : (686.9796)^2 : : (1)^3 : (1.52369)^3.$$

"The mass of the earth being far smaller than that of the sun, the moon describes a proportionally smaller area round it in a moment of time.

"So, Herschel, Saturn, and Jupiter having greater masses than the earth, their satellites make greater areas round their primaries, in a moment of time, than our moon does round the earth. Still, this third law of Kepler prevails in each secondary system. Among the satellites of the same system, the squares of the periodical times are always as the cubes of their mean distances from the primary of the system."

According to these laws, which are known to prevail throughout the Solar System, many of the facts of astronomy are deduced from other facts previously ascertained. They are, therefore, of great importance; and should be studied till they are, at least, thoroughly understood, if not committed to memory. The first is illustrated in several of the maps, and, as before said, the ingenious teacher will readily illustrate the second by a simple diagram upon a slate or black-board. It would be a very useful exercise for the pupil to test the table in which the *distances* and *periodic times* are given, by this third law. See Lessons 8 and 18.

Lesson 112.

MINIATURE REPRESENTATION OF THE SOLAR SYSTEM.

At the close of his remarks on the Primary Planets,* Sir John Herschel has a most graphic and interesting description of the Solar System in miniature, which is here inserted for the perusal of the learner.

Choose any well-levelled field or bowling-green. On it place a globe two feet in diameter: this will represent the Sun; Mercury will be represented by a grain of mustard-seed, on the circumference of a circle 164 feet in diameter for its orbit; Venus a pea, on a circle 284 feet in diameter; the Earth also a pea, on a circle of 430 feet; Mars a rather large pin's head, on a circle of 654 feet; Vesta, Juno, Ceres, and Pallas, [also Astræa,] grains of sand, in orbits of 1000 to 1200 feet; Jupiter a moderate-sized orange, on a circle nearly half a mile across; Saturn a small orange, on a circle of four-fifths of a mile; and Herschel a full-sized cherry, or small plum, upon a circumference of a circle more than a mile and a half in diameter. * * * * *

To imitate the *motions* of the planets, in the above-mentioned orbits, Mercury must revolve in its orbit in 41 seconds; Venus in 4 min. 14 sec.; the Earth in 7 min.; Mars in 4 min. 48 sec.; Jupiter in 2 h. 56 min.; Saturn in 3 h. 13 min.; and Herschel in 2 h. 16 min.

So far as relative magnitude is concerned, it will be easy to discover the general accuracy of Maps 2 and 4, according to the representations of Dr. Herschel, as above quoted. It is proper, however, to remark, that the maps were drawn by the author by a regular and exact scale, without any reference to the foregoing, or any recollection of its existence.

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* Treatise, p. 271.

Lesson 113.

WERE THE ASTEROIDS ORIGINALLY ONE PLANET?

1. Some very curious speculations have been entertained by astronomers in regard to the origin of the Asteroids. As in the case of the recently discovered planet *Le Verrier*, the existence of a large planet between the orbits of Mars and Jupiter was *suspected* before the Asteroids were known. This suspicion arose mainly from the seeming chasm that the absence of such a body would leave in the otherwise well-balanced Solar System.

2. The prediction that such a body would be discovered in the future stimulated the search of astronomers, till at length, instead of one *large* planet, *five small ones* were one after another discovered. For the time of their discovery, see Lesson 67.

3. From certain peculiarities of the Asteroids, it has been considered highly probable that they were originally one large planet, which had been burst asunder by some great convulsion or collision, and of which they are the fragments. The grounds of this opinion are as follows:

(1.) The Asteroids are much *smaller* than any of the other primary planets. Lesson 14.

(2.) They are all at nearly the same *distance* from the sun, as will be seen by Lesson 8.

(3.) Their periodic revolutions are accomplished in nearly the same time. (Lesson 18.) The difference of their periodic times is not greater than might result from the supposed disruption, as the parts thrown *forward* would have their motion *accelerated*, while the other parts would be thrown *back* or *retarded;* thus changing the periodic times of both.

(4.) The great departure of the *orbits* of the Asteroids from the plane of the ecliptic is supposed to favor the hypothesis of their having been originally one planet, the assumption being that the explosion separating the original body into fragments would not only accelerate some portions and retard others, but would also throw them out of the plane of the original orbit, and in some cases still further from the ecliptic.

(5.) Their orbits are *more eccentric* than those of the other primaries, (46.) Although the table shows the eccentricity of Herschel's orbit as greater in miles than that of even Juno or Pallas, yet when we consider the difference in the *magnitude* of their orbits, it will easily be seen that his orbit is less elliptical than theirs.

(6.) The orbits of Ceres and Pallas, at least, *cross each other*, as shown in Map 2. This, if we except perhaps the orbits of the comets, is a perfect anomaly in the Solar System.

From all these circumstances, it has been concluded that the Asteroids are only the fragments of an exploded world, which have assumed their present forms since the disruption, in obedience to the general laws of gravitation. This theory of Dr. Olbers, is favored by Prof. Nichol, Dr. Brewster, Dr. Dick, and others; while Sir John Herschel observes that it may serve as a specimen of the *dreams* in which astronomers, like other speculators, occasionally and harmlessly indulge.* Dr. Dick remarks, that the breaking up of the exterior crust of the earth, at the time of the general deluge, was a catastrophe as tremendous and astonishing as the bursting asunder of a large planet.†

The late General Root, of Delhi, was of opinion that the Asteroids were primarily *satellites of Mars;* which, as if dissatisfied with their low condition as mere attendants upon another, and one, too, not much larger than themselves, have wandered from their original spheres, and assumed the character of primaries. The *reasons* for this opinion, as stated to the author by Gen. Root, in the fall of 1846, are quite as satisfactory as the evidences by which the theory of Dr. Olbers is supported. But this is not endorsing either the one or the other. Indeed, in view of the *harmony* and *order* that everywhere reign throughout the planetary regions, directing the pathway and controlling the destiny of every world, it is hard to believe that any planet has either been broken to pieces by some mighty explosion or concussion, or wandered from its prescribed path into a new and essentially different orbit.

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* Treatise, p. 162.

† Celestial Scenery, p. 140

Lesson 114.

ARE THE PLANETS INHABITED BY RATIONAL BEINGS?

Upon this interesting question, it must be admitted, that we have no positive testimony. The argument in the affirmative is based wholly upon analogies, and the conclusion is to be regarded only in the light of a legitimate inference. Still, it is remarkable that those who are best acquainted with the facts of astronomy are most confident that other worlds, as well as ours, are the abodes of intellectual life. Indeed, as Dr. Dick well remarks, it requires a minute knowledge of the whole scenery and circumstances connected with the planetary system, before this truth comes home to the understanding with full conviction.

It is not proposed, in this lesson, to discuss at length the question of a plurality of worlds, but merely to give the heads of the arguments by which this doctrine is supported, leaving the reader to amplify them by reflection, or to pursue the inquiry, at his leisure, in more elaborate works. Perhaps no writer has done better justice to this subject than Dr. Dick,* to whom we are indebted for many of the arguments with which this lesson is enriched.

1. The planets are all *solid bodies* resembling the earth, and not mere clouds or vapors.

2. They all have a *spherical* or *spheroidal figure*, like our own planet.

3. The laws of gravitation, by which we are kept upon the surface of the earth, prevail upon all the other planets, as if to bind races of material beings to their surfaces, and provide for the erection of habitations and other conveniences of life.

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* Celestial Scenery, pp. 331–363

4. The *magnitudes* of the planets are such as to afford ample scope for the abodes of myriads of inhabitants. It is estimated that the solar bodies, exclusive of the comets, contain an area of 78,000,000,000 of square miles; or 397 times the surface of our globe. According to the population of England, this vast area would afford a residence to 21,875,000,000,000 of inhabitants; or 27,000 times the population of our globe.

5. The planets have a *diurnal revolution* around their axes, thus affording the agreeable vicissitudes of day and night. Not only are they opaque bodies like our globe, receiving their light and heat from the sun, but they also revolve so as to distribute the light and shade alternately over each hemisphere. There, too, the glorious Sun arises, to enlighten, warm, and cheer; and there "the sun-strown firmament" of the more distant heavens is rendered visible by the no less important blessing of a periodic night.

It is very remarkable, also, that those planets whose bulks are such as to indicate an insupportable attractive force, are not only less dense than our globe, but they have the most rapid daily revolution; as if by diminished density, and a strong centrifugal force combined, to reduce the attractive force, and render locomotion possible upon their surfaces.

6. All the planets have an *annual revolution* round the sun; which, in connection with the inclination of their axes to their respective orbits, necessarily results in the production of *seasons.*

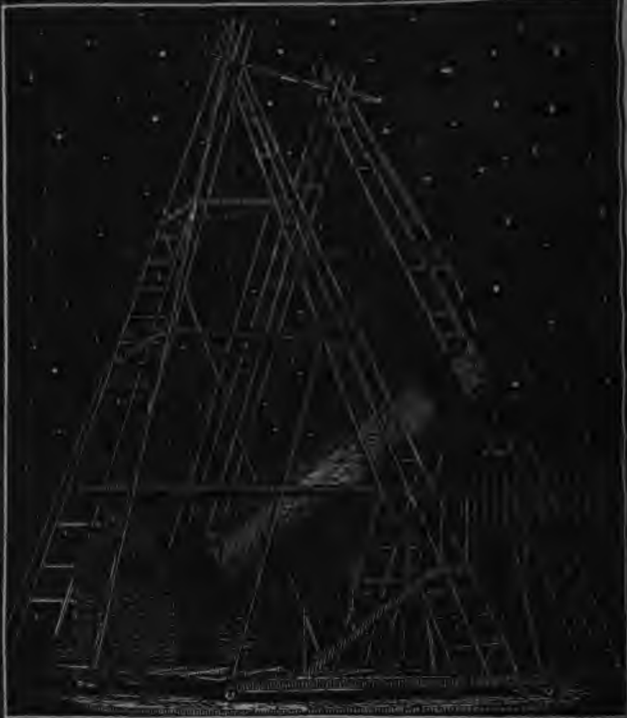
7. The planets, in all probability, are enveloped in *atmospheres*. That this is the case with many of them is certain; and the fact that a fixed star or any other orb is not rendered dim or distorted when it approaches their margin, is no evidence that the planets have no atmosphere. This appendage to the planets is known to vary in density; and in those cases where it is not detected by its intercepting or refracting the light, it may be of a nature too clear and rare to produce such phenomena.

8. The principal primary planets are provided with *moons* or *satellites,* to afford them light in the absence of

the sun. It is not improbable that both Mars and Venus have each, at least, one moon. The earth has one, and as the distances of the planets are increased, the number of moons seems to increase. The discovery of only six around Herschel is no evidence that others do not exist which have not yet been discovered.

9. The surfaces of all the planets, primaries as well as secondaries, seem to be variegated with *hill and dale*, with *mountain and plain*.

Every part of the globe we inhabit is destined to the support of animal life. It would, therefore, be contrary to the analogy of nature, as displayed to us, to suppose that the other planets are empty and barren wastes, utterly devoid of animated being. The inquiry presses itself upon the mind with irresistible force, Why should this one small world be inhabited, and all the rest unoccupied ? For what purpose were all these splendid and magnificent worlds fitted up, if not to be inhabited ? Why these days and years—this light and shade—these atmospheres, and seasons, and satellites, and hill and dale ? The legitimate, and almost inevitable conclusion is, that our globe is only *one* of the *many worlds* which God has created to be inhabited, and which are now the abodes of his intelligent offspring. It is revolting to suppose that we of earth are the only intelligent subjects of the "GREAT KING," whose dominions border upon infinity.



SIR WILLIAM HERSCHELS
40 FEET REFLECTOR.

THIS CELEBRATED INSTRUMENT IS AT SLOUGH, ENGLAND: IT IS 4 FEET IN DIAMETER & THE TUBE MADE OF SHEET-IRON IS 39 FEET 4 INCHES LONG IT WAS COMPLETED AUG 27. 1780: THE FIRST MOMENT IT WAS DIRECTED TO THE HEAVENS, THE 6TH, MOON OF SATURN WAS DISCOVERED. IN THE CUT THE OBSERVER MAY BE SEEN IN A MOVEABLE-SEAT AT THE MOUTH OF THE TUBE LOOKING AT THE HEAVENS IN THE CONCAVE METALIC MIRROR AT THE BOTTOM

PART II.

THE SIDEREAL HEAVENS.

CHAPTER I.

OF CONSTELLATIONS OF STARS.

Lesson 115.

DISTINGUISHING CHARACTERISTICS OF THE FIXED STARS.

THE Sidereal Heavens embrace all those celestial bodies that lie around and beyond the Solar System, in the region of the Fixed Stars.

The Fixed Stars are distinguished from the Solar Bodies by the following characteristics:

1. They shine *by their own light*, like the sun, and not by *reflection*.

2. To the naked eye they seem to *twinkle* or *scintillate;* while the planets appear tranquil and serene.

3. They maintain the same *general positions* with respect to each other, from age to age.

4. They are inconceivably *distant*, so that when viewed through a telescope they present no sensible disc, but appear only as shining points on the dark concave of the sky.

To these might be added several other peculiarities which will be noticed in the sequel, but they are not necessary to our present purpose.

Lesson 116.

CLASSIFICATION OF THE STARS.

(Map **16.**)

For purposes of convenience in finding or referring to particular stars, recourse is had to a variety of artificial methods of classification, with which the pupil should here become acquainted.

1. The whole concave of the heavens is divided into sections of greater or less extent, called *Constellations.* For the origin of these most unnatural and arbitrary divisions, consult Lesson 36. A list of the constellations will be found in a subsequent chapter.

2. The stars are all classed according to their *magnitudes.* There are usually reckoned twelve different magnitudes, of which the first six only are visible to the naked eye, the rest being *telescopic stars.* This magnitude, of course, relates only to their apparent brightness, as the faintest star may appear dim solely on account of its immeasurable distance.

Fig. A on the map is a representation of the first eight magnitudes, the two smallest of which will be invisible to the pupil at a distance. "It must be observed," says Dr. Herschel, "that this classification into magnitudes is entirely arbitrary. Of a multitude of bright objects, differing, probably, intrinsically both in size and in splendor, and arranged at unequal distances from us, one must of necessity appear the brightest; the one next below it brighter still, and so on."

3. The next step is to classify the stars of *each constellation* according to their magnitude *in relation to each other*, and without reference to other constellations. In this classification the Greek alphabet is first used. For instance, the largest star in Taurus would be marked (α) Alpha; the next largest (β) Beta; the next (γ) Gamma, &c. When the Greek alphabet is exhausted, the Roman or English is taken up; and when these are all absorbed, recourse is finally had to figures.

4. To aid still further in finding particular stars, and especially in determining their numbers, and detecting changes, should any occur, astronomers have constructed *Catalogues* of the stars, one of which is near 2,000 years old.

5. Several of the principal stars have a specific name like the planets; as *Sirius*, *Aldebaran*, *Regulus*, &c.

6. Clusters of stars in a constellation sometimes re-

ceive a specific name, as the *Pleiades* and *Hyades* in Taurus.

7. The stars are still further distinguished into Double, Triple, and Quadruple stars; Binary System; Variable Stars; Periodic Stars; Nebulous Stars, &c.; all of which will be duly noticed as we proceed. But we must first consider the more general divisions of the starry heavens.

Lesson 117.

NUMBER OF THE FIXED STARS.

The actual *number* of the stars is known only to Him who "telleth the number of the stars," and "calleth them all by their names." The powers of the human mind are barely sufficient to form a vague estimate of the number near enough to be seen by our best telescopes, and here our inquiries must end.

The number of stars down to the twelfth magnitude, has been estimated as follows:

Visible to the naked eye,	1st magnitude,		18	
	2d	"	52	
	3d	"	177	
	4th	"	376	
	5th	"	1,000	
	6th	"	4,000	
				5,623
Visible only thro' tel'scopes,	7th	"	26,000	
	8th	"	170,000	
	9th	"	1,100,000	
	10th	"	7,000,000	
	11th	"	46,000,000	
	12th	"	300,000,000	
				354,296,000
			Total number,	354,301,623

Of these stars, Dr. Herschel remarks that from 15,000 to 20,000 of the first seven magnitudes are already *registered*, or noted down in catalogues; and Prof. Olmsted observes that Lalande has registered the positions of no less than 50,000.

"If we suppose," says an eloquent writer, "that each of these suns is accompanied only by as many planets as are embraced in our Solar System, we have *five thousand millions of worlds* in our firmament. No human mind can form a conception of this number; but even these, as will hereafter be shown, form but a minute and comparatively insignificant portion of the boundless empire which the Creator has reared, and over which he reigns. Eternal ages may glide joyfully along, as the Christian explores these wonderful worlds, of every variety of form and character, and partakes of the hospitalities of their blissful inhabitants. It is pleasant to tread the pavements of a foreign city—to traverse the glaciers of the Alps—to glide over the surface of the Nile in the midst of the mouldering remains of its past grandeur; but what are all these, compared to the journey of a rejoicing spirit to these sublime mansions of the Deity?"

Lesson 118.

DISTANCES OF THE STARS.

It has been demonstrated that the *nearest* of the fixed stars cannot be less than 20,000,000,000,000—*twenty billions* of miles distant! For light to travel over this space at the rate of 200,000 miles per second, would require 100,000,000 seconds, or upwards of three years.

What then must be the distances of the telescopic stars, of the 10th and 12th magnitudes? "If we admit," says Dr. Herschel, "that the light of a star of each magnitude is half that of the magnitude next above it, it will follow that a star of the first magnitude will require to be removed to 362 times its distance, to appear no larger than one of the twelfth magnitude. It follows, therefore, that among the countless multitude of such stars, visible in telescopes, there must be many whose light has taken at least a thousand years to reach us; and that when we observe their places, and note their changes, we are, in fact, reading only their history of a thousand years' date, thus wonderfully recorded."

Should such a star be struck out of existence now, its light would continue to stream upon us for a thousand years to come; and should a new star be created in those distant regions, a thousand years must pass away before its light could reach the Solar System, to apprize us of its existence.

Lesson 119.

MAGNITUDE OF THE STARS.

From what we have already said respecting the almost inconceivable distances of the fixed stars, it will readily be inferred that they must be bodies of great magnitude, in order to be visible to us upon the earth. It is probable, however, that "one star differeth from another" in its intrinsic splendor or "glory," although we are not to infer that a star is comparatively small, because it appears small to us.

The prevailing opinion among astronomers is, that what we call the fixed stars are so many *suns*, and centres of other systems. By a series of experiments upon the light received by us from Sirius, the nearest of the fixed stars, it is ascertained that if the sun were removed 141,400 times his present distance from us, or thirteen billions of miles, his light would be no stronger than that of Sirius; and as Sirius is more than twenty billions of miles distant, he must, in intrinsic magnitude and splendor, be equal to two suns like ours. Dr. Wollaston, as cited by Dr. Herschel, concludes that this star must be equal in intrinsic light to nearly fourteen suns!

According to the measurements of Sir Wm. Herschel, the diameter of the star *Vega* in the Lyre, is 38 times that of the sun, and its solid contents 54,872 times greater! The star numbered 61 in the Swan, is estimated to be 200,000,000 miles in diameter.

Sir John Herschel states that while making observations with his forty-feet reflector, a star of the first magnitude was unintentionally brought into the field of view. "Sirius," says he, "announced his approach like the dawn of day;" and so great was his splendor when thus viewed, and so strong was his light, that the great astronomer was actually driven from the eye-piece of his telescope by it, as if the sun himself had suddenly burst upon his view. He was obliged to employ a colored screen, as in the case of solar observations, to protect his eye from the strong and glowing radiance.

According to Sir Wm. Herschel, the relative light of the stars of the first six magnitudes is as follows:

Light	of a star	of the average	1st	magnitude	100
"	"	"	2d	"	25
"	"	"	3d	"	12
"	"	"	4th	"	6
"	"	"	5th	"	2
"	"	"	6th	"	1

Lesson 120.

LIST OF THE CONSTELLATIONS.

Of the *nature* and *origin* of the constellations we have already spoken in Lesson 36. Their formation has been the work of ages. Some of them were known at least 3,000 years ago, and bore the very names by which they are known to this day. In the 9th chapter of Job we read of "Arcturus, Orion, and Pleiades, and the chambers of the south;" and in the 38th chapter of the same book, it is asked, "Canst thou bind the sweet influences of Pleiades, or loose the bands of Orion? Canst thou bring forth Mazzaroth in his season? or canst thou guide Arcturus with his sons?"

At first the number of constellations was few. Being found convenient in the study of the heavens, new ones were added to the list, composed of stars not yet made up into hydras and dragons, till there is now scarcely stars or room enough left to construct the smallest new constellation, in all the spacious heavens.

The constellations are divided into the *Zodiacal*, the *Northern*, and the *Southern*.

The *Zodiacal Constellations* are those which lie in the sun's apparent path, or along the line of the Zodiac. See Lesson 36, and the map.

The *Northern Constellations* are those which lie between the Zodiacal and the North Pole of the heavens.

The *Southern Constellations* lie between the Zodiacal and the South Pole of the heavens.

The constellations are also distinguished into *ancient* and *modern*. The following is a list of all the constellations, both ancient and modern, with the number of principal stars in each, according to Ptolemy's Catalogue, and also that of the Observatory Royal of Paris.

I.

ZODIACAL CONSTELLATIONS.

		Latin names.	English names.	Ptol's.	Ob. R.
1	♈	Aries.	*The Ram.*	18	42
2	♉	Taurus.	*The Bull.*	44	207
3	♊	Gemini.	*The Twins.*	25	64
4	♋	Cancer.	*The Crab.*	33	85
5	♌	Leo.	*The Lion.*	35	93
6	♍	Virgo.	*The Virgin.*	32	117
7	♎	Libra.	*The Scale.*	07	67
8	♏	Scorpio.	*The Scorpion.*	27	60
9	♐	Sagittarius.	*The Archer.*	31	94
10	♑	Capricornus.	*The Goat.*	28	64
11	♒	Aquarius.	*The Water-bearer.*	45	117
12	♓	Pisces.	*The Fishes.*	38	116

II.

NORTHERN CONSTELLATIONS.

ANCIENT.

13	Ursa Minor.	*The Little Bear*	08	22
14	Ursa Major.	*The Great Bear.*	34	87
15	Draco.	*The Dragon.*	31	85
16	Cepheus.	*Cepheus.*	13	58
17	Bootes.	*Bootes.*	23	70

	Latin names.	English names.	Ptol's.	Ob. R.
18	CORONA BOREALIS.	*The Northern Crown.*	08	33
19	HERCULES.	*Hercules.*	29	128
20	LYRA.	*The Harp.*	10	21
21	CYGNUS.	*The Swan.*	10	85
22	CASSIOPEIA.	*Cassiopeia.*	13	60
23	PERSEUS.	*Perseus.*	29	65
24	AURIGA.	*The Charioteer.*	14	69
25	OPHIUCHUS.	*The Serpent-bearer.*	29	61
26	SAGITTA.	*The Arrow.*	05	18
27	AQUILA.	*The Eagle.*	15	26
28	DELPHINUS.	*The Dolphin.*	10	19
29	EQUULEUS.	*The Little Horse.*	04	10
30	PEGASUS.	*Pegasus.*	20	91
31	ANTINOUS.	*Antinous.*	15	28
32	ANDROMEDA	*Andromeda.*	23	71
33	TRIANG. BOREALIS.	*The North. Triang.*	04	15
34	COMA BERENICES.	*Berenice's Hair.*	35	43

MODERN.

35	LEO MINOR.	*The Little Lion*	—	55
36	CANES VENATICI.	*The Greyhounds*	—	38
37	SEXTANS.	*The Sextant.*	—	54
38	CERBERUS.	*Cerberus.*	—	13
39	TAURUS PONIATOWSKI.	*Poniatowski's Bull.*	—	18
40	VELPECULA ET ANS.	*The Fox and Goose.*	—	35
41	LACERTA.	*The Lizard.*	—	12
42	TRIANGULA MINORA.	*The Little Triangle.*	—	04
43	MUSCA BOREALIS.	*The Northern Fly.*	—	05
44	TARANDUS.	*The Reindeer.*	—	12
45	CUSTOS MESSIUM.	*The Harvester.*	—	07
46	CAMELOPARDALUS.	*The Camelopard*	—	69
47	LINX.	*The Lynx.*	—	45

III.

SOUTHERN CONSTELLATIONS.

ANCIENT.

48	CETUS.	*The Whale.*	22	102
49	ERIDANUS.	*The River Po.*	34	85

Latin names.	English names.	Ptol's.	Ob. R.
50 Orion.	*Orion.*	38	90
51 Lepus.	*The Hare.*	12	20
52 Canis Minor.	*The Little Dog.*	02	17
53 Canis Major.	*The Great Dog.*	29	54
54 Argo Navis.	*The Ship Argo.*	45	117
55 Hydra.	*The Water Serpent.*	27	52
56 Crater.	*The Cup.*	07	13
57 Corvus.	*The Crow.*	07	10
58 Centaurus.	*The Centaur.*	37	48
59 Lupus.*	*The Wolf.*	19	34
60 Ara.	*The Altar.*	07	08
61 Corona Australis.	*The Southern Crown.*	13	12
62 Piscis Australis.	*The Southern Fish.*	18	24

MODERN.

63 Fornax Chimica.	*The Chemic. Furn.*	—	39
64 Reticulis Rhomb.	*The Rhombed Net.*	—	07
65 Cela Sculptoria.	*The Engraver's Tool.*	—	15
66 Dorado vel Xyph.	*The Sword-fish.*	—	06
67 Columba Noachi.	*The Dove.*	—	02
68 Equuleus Pict.	*The Painter's Easel.*	—	04
69 Monoceros.	*The Unicorn.*	—	31
70 Pyxis Nautica.	*The Mariner's Compass.*	—	14
71 Autlia Pneumat.	*The Air-pump.*	—	22
72 Avis Solit.	*The Solitary Bird.*	—	23
73 Crux Australis.	*The Southern Cross.*	—	06
74 Musca Australis	*The Southern Fly.*	—	04
75 Chameleonis.	*The Chameleon.*	—	07
76 Piscis Volans.	*The Flying-fish.*	—	06
77 Telescopium.	*The Telescope.*	—	08
78 Horologium.	*The Pendulum, &c.*	—	23
79 Norma Euclidis	*Euclid's Square.*	—	15
80 Circinus.	*The Compasses.*	—	02
81 Triang. Australis.	*The Southern Triangle.*	—	05
82 Ap. vel Av. Indica.	*The Bird of Paradise.*	—	04
83 Mons Mensa.	*Mount of Table Bay.*	—	06
84 Scutum Sobieski.	*Sobiesky's Shield.*	—	16
85 Indus	*The Indian.*	—	04
86 Pavo.	*The Peacock.*	—	11

Latin names.	English names.	Ptol's.	Ob. R.
87 OCTANS.	*The Octant.*	—	07
88 MICROSCOPIUM.	*The Microscope.*	—	08
89 GRUS.	*The Crane.*	—	12
90 TOUCHANA	*The Amer. Goose.*	—	11
91 HYDRUS.	*The Water-snake.*	—	08
92 APPARATUS SCULP.	*The Sculptor's Studio.*	—	28
93 PHŒNIX.	*The Phœnix.*	—	11

RECAPITULATION.

Zodiacal Constellations,	12	Principal stars,	1125
Northern "	35	" "	1531
Southern "	46	" "	1050
Total,	93	Total,	3706

Lesson 121.

DESCRIPTION OF SOME OF THE PRINCIPAL CONSTELLATIONS.

Although this work is designed particularly to illustrate the Mechanism of the Heavens, as displayed in the Solar System, we are desirous of furnishing the learner with a sufficient guide to enable him to extend his inquiries and investigations, not only to the different *classes* of bodies lying beyond the limits of the Solar System, in the far-off heavens, but also to the *Constellations* as such. For this purpose we shall here furnish a brief description of the principal constellations visible in the United States, or in north latitude, by the aid of which the student will be able to trace them, with very little difficulty, upon that glorious celestial atlas which the Almighty has spread out before us.

These descriptions are partly original, and partly from the writings of Olmsted and Burritt.

ZODIACAL CONSTELLATIONS.

The Constellations of the Zodiac, succeeding each other in regular order eastward, and being more easily found on that account than others, should first be studied.

ARIES is a small constellation known by two bright stars, about 4° apart, which form the head. The brightest is the most northeasterly of the two.

TAURUS will be readily found by the seven stars or *Pleiades*, which lie in his neck. The largest star in Taurus is *Aldebaran*, in the Bull's eye, a star of the first magnitude, of a reddish color, somewhat resembling the planet Mars. Aldebaran, and four other stars in the face of Taurus, compose the *Hyades*. They are so placed as to form the letter V.

GEMINI is known by two very bright stars, *Castor* and *Pollux*, about five degrees apart.

CANCER is less remarkable than any other constellation of the Zodiac. It has no stars larger than the third magnitude, and is distinguished for a group of small stars called the Nebula of Cancer, which is often mistaken for a comet. A common telescope resolves this nebula into a beautiful assemblage of bright stars.

LEO is a large and interesting constellation, containing an unusual number of very bright stars. Of these, *Regulus* is of the first magnitude, and lies directly in the ecliptic. North of Regulus are several bright stars in the form of a sickle, of which Regulus is the handle. *Denebola* is a bright star of the second magnitude, in the Lion's tail. It is about 25° northeast of Regulus, and 35° west of Arcturus.

VIRGO extends for some distance from west to east, but contains only a few bright stars. Of these, *Spica* in the ear of corn which the Virgin holds in her left hand, is a brilliant star of the first magnitude. The rest of her principal stars are of the third and fourth magnitudes.

LIBRA may be known by its four principal stars, forming a quadrilateral figure. The two brightest of these constitute the *beam* of the balance, and the smallest is in the top or handle.

SCORPIO is one of the most interesting and splendid of the constellations. His head consists of five bright stars, forming the arc of a circle, and is crossed by the ecliptic near the brightest of the five. Nine degrees southeast is the star *Antares*, of a reddish color, and of the first magnitude. A number of small stars that curve around towards the east constitute the tail of Scorpio.

SAGITTARIUS lies next to Scorpio, and may be known by three stars arranged in a curve, to represent the *bow* of the Archer, the central star being the brightest, and having a bright star directly west of it, forming the head of the *arrow*.

CAPRICORNUS lies northeast of Sagittarius, and may be known by two bright stars close together, which constitute the head.

AQUARIUS is represented by the figure of a man pouring water out of a vessel. Its four largest stars are of the third magnitude. Two of these, which lie in a line with the brightest stars in Capricornus, constitute the head of the figure.

PISCES, the last of the Zodiacal constellations, lies between Aquarius and Aries. The Southern Fish consists of 24 visible stars, of which one is of the first magnitude, two of the third, and five of the fourth. The remaining 16 are smaller. The largest star is situated in the mouth of the Fish, and is called *Fomalhaut*. The Northern Fish consists wholly of small stars, and is connected with the Southern by a series of stars forming a crooked line between them.

Lesson 122.

NORTHERN CONSTELLATIONS.

The Constellations of the Zodiac being first well learned, so as to be readily recognised, will facilitate the learning of others that lie *north* and *south* of them. Let us, therefore, review the principal *Northern Constella-*

tions, beginning north of Aries and proceeding from west to east.

ANDROMEDA may be known by three stars of the second magnitude, situated in a straight line, and extending from east to west. The figure is that of a woman, with her arms extended, and chained by her wrists to a rock. The middle star, of the three just named, is situated in her *girdle*, and is called *Mirach*. The one west of Mirach is in the *head* of Andromeda, and the eastern one, called *Almaak*, is in her *left foot*. The star in her head is in the Equinoctial Colure. The three largest stars in this constellation are of the second magnitude. Near Mirach are two stars of the third and fourth magnitudes, and the three in a row constitute the girdle.

The loose assemblage of small stars directly south of Mirach, are the Northern Fish, already described.

PERSEUS lies directly north of the Pleiades, and east of Andromeda. The figure is that of a man with a sword in his right hand, and the head of Medusa in his left. About 18°. from the Pleiades is *Algol*, a star of the second magnitude, in the head of Medusa; and 9° north-east of Algol is *Algenib*, of the same magnitude, in the back of Perseus. It has, also, four stars of the third magnitude.

Algol will be mentioned again, under the head of Variable Stars.

AURIGA (*The Wagoner*) is the figure of a man in a declining posture, resting one foot upon the horn of Taurus. It is north of Taurus and Orion, and directly east of Perseus. *Capella*, the principal star in this constellation, is one of the most brilliant in the heavens. It is in the west shoulder of Auriga, and may be known by a small triangle near it, formed by three small stars.

The LYNX comes next in order, but presents nothing particularly interesting, as it contains no stars above the fourth magnitude, and even these are scattered over a large space north of Gemini, and between Auriga and Ursa Major.

Leo Minor is composed of a few small stars lying between the sickle in Leo, and the Great Bear.

Coma Berenices is a beautiful cluster of small stars, north of Denebolis, in the tail of the Lion, and north of the head of Virgo. It has but one star as large as the fourth magnitude. *Cor Caroli*, or Charles's Heart, is a bright star about 12° directly north of Coma Berenices.

Bootes is the figure of a man with a club in his right hand, with which he seems to be driving the Great Bear round the pole of the heavens. He is thence called the Bear Driver. Arcturus, situated near the left knee, is a star of the first magnitude, and of a reddish color. He is accompanied by three small stars, (his "sons,"*) which form a triangle a little to the southwest. A star of the second magnitude is in the head of the figure, and two bright stars of the third magnitude form the shoulders.

Corona Borealis (*The Crown*) is situated between Bootes on the west, and Hercules on the east. It consists of six principal stars, in the form of a wreath or crown.

Alphacca, the largest star of the group, is of the third magnitude, and may be known by its position in the centre of the crown, as well as by its superior brightness.

Hercules lies immediately east of the crown, and occupies a large space in the Northern hemisphere. The figure is that of a giant, with a large club in his right hand. The head is towards the south.

This constellation is thickly set with stars, the largest of which is called *Rasalgethi*, in the head of the figure, and is of the second magnitude. It has nine stars of the third magnitude, and nineteen of the fourth.

Ophiuchus (*The Serpent-bearer*) is situated directly south of Hercules, with its centre nearly over the equator, and nearly opposite to Orion. The figure is that of a venerable-looking man, grasping a serpent in his hands, the *head* of which consists of three bright stars, situated a little south of the crown. The *folds* of the serpent may be traced by a succession of bright stars extending for some distance to the east.

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* Job xxxviii. 32.

The principal star in Ophiuchus is of the second magnitude, and is called *Ras Alhague*. It is situated in the *head* of the figure, and within 5° of Rasalgethi, in the head of Hercules.

Aquila (*The Eagle*) is conspicuous for three bright stars in its neck, of which the central one, *Altair*, is a brilliant white star of the first magnitude. *Antinous* lies directly south of the Eagle, and north of the head of Capricornus.

Delphinus (*The Dolphin*) is a beautiful little cluster of stars, a little to the east of the Eagle. It may be known by four principal stars in the head, of the third magnitude, arranged in the figure of a diamond, and pointing northeast and southwest. A star of the same magnitude, about 5° south, makes the tail.

Pegasus is a large constellation situated between the Dolphin and Eagle, on the west, and Andromeda and the Northern Fish, on the northeast. The figure is that of a winged horse, in an inverted posture. It may be known by four stars about 15° apart, forming a *square* called the square of Pegasus. They are of the second and third magnitudes, and one of them, viz. *Algenib*, bears the same name as a star in Perseus.

The Horse's Head is a small cluster of stars, west of the head of Pegasus, and about half way to the Dolphin. It contains ten stars, of which the four principal are only of the fourth magnitude. They form a long irregular square, the two in the nose being 1° apart, and those in the eyes 2½°. These four stars are about 1° southeast of the diamond in the head of the Dolphin.

We now come to notice the constellations around the

North Pole, and which are always above the horizon in northern latitudes.

Ursa Minor (*The Little Bear*) is near the north pole of the heavens. It consists of the *Pole Star*, as it is called, which forms the extremity of the tail, and six other principal stars, three of the third, and four of the fourth magnitudes. The seven together are arranged in the form of a *dipper*, with the Pole Star in the end of the handle.

Ursa Major (*The Great Bear*) may be known by the figure of a larger *dipper*, which constitutes the hinder part of the animal. This dipper, also, is composed of seven stars. The first, in the end of the handle, is called *Benetnash*, and is of the second magnitude. The next is *Mizar*, known by a minute star almost touching it, called *Alcor*. *Mizar* is a double star. The third in the handle is *Alioth*. The first star in the bowl of the dipper, at the junction of the handle, is *Megrez*. Passing to the bottom of the dipper we find *Phad* and *Merak*, while *Dubhe* forms the rim opposite the handle. Merak and Dubhe are called the *Pointers;* because they always point towards the Pole Star.

The *head* of the Great Bear lies far to the west of the Pointers, and is composed of numerous small stars; while the *feet* are severally composed of two small stars, very near to each other.

Draco (*The Dragon*) compasses a large circuit in the polar regions. He winds round between the Great and Little Bear, and commencing with the tail, between the Pointers and Pole Star, it is easily traced by a succession of bright stars extending from west to east; passing under Ursa Minor, it returns westward, and terminates in four stars which form the head, near the foot of Hercules. These four stars are 3°, 4°, and 5° apart, so situated as to form an irregular square; the two upper ones being the brightest, and both of the second magnitude.

Cepheus lies east of the breast of Draco, but has n stars above the second magnitude. The figure is that o a king, crowned, and with a sceptre in his left hand, which is extended towards Cassiopeia.

Cassiopeia is a queen on a throne or chair, with her head and body in the Milky Way. The chair is composed of four stars, which form the legs, and two constituting the back. Five of these are of the third magnitude.

Lyra (*The Lyre*) is distinguished by one of the brightest stars in the northern hemisphere. It is situated east of Hercules, and between him and the Swan. Its largest star is *Vega*, or *Alpha Lyra*, and is of the first magnitude. It has two others of the second magnitude, and several of the fourth.

Cygnus (*The Swan*) is situated directly east of Lyra. Three bright stars, which lie along the Milky Way, form the *body* and *neck* of the Swan; and two others, in a line with the middle one of the three, constitute the *wings*. These five stars form a large *cross*.

Arided, in the body of the Swan, is a star of the first magnitude, and the remaining ones of the constellation are of the third and fourth magnitudes.

Camelopardalus (*The Camelopard*) is a large and uninteresting field of small stars, scattered between Perseus, Auriga, the head of Ursa Major, and the Pole Star. Its five largest stars are only of the fourth magnitude, the principal of which is in the thigh. The head of the animal is near the pole.

The Lynx also is composed of small stars, scattered over a large extent. It lies north of Gemini, and between Auriga and Ursa Major. Its three largest stars are ot the third magnitude.

Lesson 123.

SOUTHERN CONSTELLATIONS.

The Southern Constellations are comparatively few in number, though some of them are very beautiful.

Cetus (*The Whale*) is the largest constellation in the heavens. It is situated below or south of Aries. It is represented with its head to the east, and extends 50° east and west, with an average breadth of 20°.

The *head* of Cetus may be known by five remarkable stars, 4° and 5° apart, and so situated as to form a regular pentagon, or five-sided figure. *Menkar*, of the second magnitude, in the nose of the Whale, is the largest star in the group, or in the constellation.

Orion lies south of Taurus, and is one of the most conspicuous and beautiful of the constellations. The figure is that of a man in the act of assaulting the Bull, with a sword in his belt, and a club in his right hand. It contains two stars of the first magnitude, four of the second, three of the third, and fifteen of the fourth. *Betelguese* forms the right, and *Bellatrix* the left shoulder. A cluster of small stars forms the head. Three small stars, forming a straight line about 3° in length, constitute the *belt*, called by Job "the *Bands of Orion*." They are sometimes called the *Three Kings*, because they point out the Hyades and Pleiades on the one hand, and Sirius on the other. A row of very small stars runs down from the belt, forming the *sword*. These, with the stars of the belt, are sometimes called the *Ell and Yard*.

Mintika, the northernmost star in the belt, is less than ½° south of the equinoctial.

Rigel, a bright star of the first magnitude, is in the left foot, 15° south of Bellatrix; and *Saiph*, of the third magnitude, is situated in the right knee, 8½° east of Rigel.

Lepus (*The Hare*) is directly south of Orion. It may be known by four stars of the third magnitude, in the form of an irregular square. *Zeta*, of the fourth magnitude, is the first star, situated in the back, and about 5° south of Saiph in Orion. About the same distance below Zeta are the four principal stars, in the legs and feet.

Columba (*Noah's Dove*) lies about 16° south of Lepus It contains but four stars, of which *Phaet* is the brigh est. It lies on the right, a little higher than *Beta*, the next brightest. This last may be known by a small star just east of it.

ERIDANUS (*The River Po*) is a large and irregular constellation, very difficult to trace. It is 130° in length, and is divided into the *Northern* and *Southern* streams. The former lies between Orion and Cetus, commencing near Rigel in the foot of Orion, and flowing out westerly in a serpentine course, near 40°, to the Whale.

CANIS MAJOR lies southeast of Orion, and may be readily found by the brilliancy of its principal star *Sirius*. This is the largest of the Fixed Stars, and is supposed to be the nearest to the Solar System.

CANIS MINOR is a small constellation situated between Canis Major and the Twins. It has but two principal stars, namely, *Procyon* of the first magnitude, and *Gomelza* of the second.

MONOCEROS (*The Unicorn*) lies between Canis Major and Canis Minor, with its centre directly south of Procyon. Its largest stars are of the fourth magnitude. Three of these are in the head, 3° and 4° apart.

HYDRA has its head near Procyon, and consists of a number of stars of ordinary brightness. *Alphard*, in the heart, is a star of the second magnitude, about 15° southeast of the head. It is an extensive constellation, extending from east to west more than 100°.

CORVUS (*The Crow*) is represented as standing upon the tail of Hydra, south of Coma Berenices. It contains but nine visible stars, only three of which are as large as the third magnitude.

ARGO NAVIS (*The Ship Argo*) is a large and splendid constellation in the southern hemisphere, but so low down in the south that but little of it can be seen in the United States. It lies southeast of Canis Major, and may be known by the stars in the prow of the ship. *Markeb*, of the third magnitude, is 16° southeast of Sirius. *Naos* and

Gamma are of the second magnitude, and *Canopus* and *Miaplacidus* of the first.

CENTAURUS is another large southern constellation, too low in the south to be traced by an observer in the United States.

LUPUS (*The Wolf*) is next east of Centaurus, south of Libra, and is also invisible in northern latitudes.

SEXTANS (*The Sextant*) consists of a number of very small stars, situated between Leo on the north, and Hydra on the south. Its largest star is of the fourth magnitude, and is situated about 13° south of Regulus, near the equinoctial.

CRUX (*The Cross*) is a brilliant little constellation, but too far south to be visible to us at the north. It consists of four principal stars, namely, one of the first, two of the second, and one of the third magnitude.

CHAPTER II.

OF DOUBLE, VARIABLE, AND TEMPORARY STARS, BINARY SYSTEMS, &c.

Lesson 124.

OF DOUBLE, TRIPLE, AND MULTIPLE STARS.

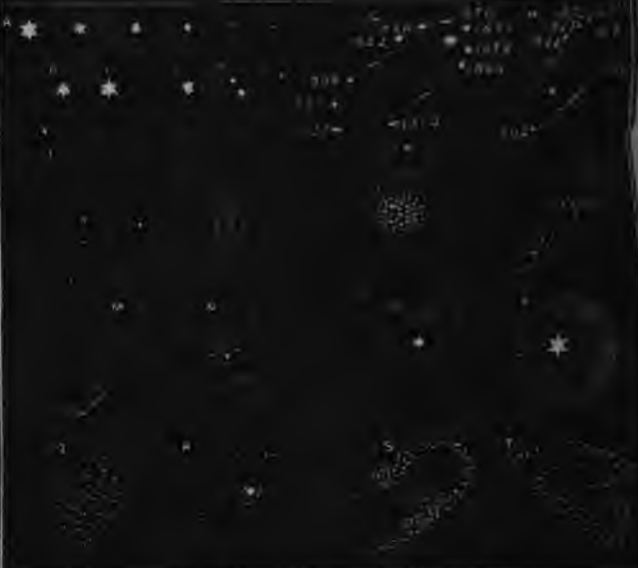
(Map 16.)

1. MANY of the stars which, to the naked eye, appear single, are found, when examined by the aid of a telescope, to consist of two or more stars, in a state of near proximity to each other. These are called *double stars*. When three or more stars are found thus closely connected, they are called *triple* or *multiple* stars. They are also distinguished as *binary*, *ternary*, &c.

2. Double and triple stars are supposed to be constituted in two ways: first, by actual contiguity; and sec-

MAP No. 16.

CLUSTERS OF STARS BINARY SYSTEMS AND NEBULÆ



THIS MAP ILLUSTRATES

THE USUAL METHOD OF CLASSIFYING THE STARS
THEIR MAGNITUDES . . . . P. 182
THE TELESCOPIC APPEARANCE OF SEVERAL DOUBLE
STARS & BINARY SYSTEMS . . . P. 180 187
THE SUBJECT OF CLUSTERS OF STARS, & THEIR
TELESCOPIC APPEARANCE . . . P. 194 196
THE TELESCOPIC APPEARANCE OF SEVERAL REMOTE CLUSTERS
CALLED NEBULAE FOUND IN DIFFERENT PARTS OF THE HEAVENS . 196,205

ondly, where they are only near the same line of vision, one of the component stars being far beyond the other. In the former case they are said to be *physically* double, from the belief that they are bound together by attraction, and that one revolves around the other, while in the latter case they are considered as only *optically* double.

Upon this subject Dr. Herschel remarks, that this nearness of the stars to each other, in certain cases might be attributed to some accidental cause, did it occur only in a few instances; but the frequency of this companionship, the extreme closeness, and, in many cases, the near equality of the stars so conjoined, would alone lead to a strong suspicion of a more near and intimate relation than mere casual juxtaposition.

3. The figures from B to F on the map are specimens of double stars. B is a representation of the middle star, *Mizar*, in the tail of the Great Bear. It may be seen double with a good spyglass. The stars are both of a greenish white—of the third and fourth magnitudes—and about 14″ apart. Mizar has sometimes been seen *without a companion*, and at other times it has been known suddenly to appear. The companion is not *Alcor*, near Mizar, and visible to the naked eye, but *a telescopic star*.

C is a view of the double star *Mintika*, in the constellation Orion. The component stars are of the first and eighth magnitudes, the largest of a reddish hue, and the small one white. They are about 10″ apart, or four times the diameter of the largest star.

D is a double star in *Ursa Minor*, commonly known as the Pole star. It consists of a star of the second and another of the ninth magnitude, situated about 18″ apart; or about four times the diameter of the larger star. They are both of a silvery white.

It requires a pretty good telescope to show this star double, hence it is considered a pretty good *test object*, by observing which to ascertain the qualities of an optical instrument, especially of the low-priced refractors.

E is a view of the double star *Castor* in the twins.

The stars are of a greenish color, of the third and fourth magnitudes, and about 5″, or two diameters of the principal star, apart. This also is considered a good test object. Through ordinary telescopes the stars seem to be in contact, but with those of higher power they appear fairly divided. These stars also constitute a binary system.

The stars under F are specimens of other distances and combinations of magnitudes.

4. The *number* of double stars has been variously estimated. Sir William Herschel enumerates upwards of five hundred, the individuals of which are within 30″ of each other. Professor Struve of Dorpat estimated the number at about three thousand, and more recent observations fix the number at not less than six thousand.

The great number of the double stars first led astronomers to suspect a physical connection by the laws of gravitation, and also a *revolution* of star around star, as the planets revolve around the sun.

Lesson 125.

OF BINARY AND OTHER SYSTEMS.

(Map 16.)

1. By carefully noting the relative distances and angular positions of double and multiple stars, for a series of years, it has been found that many of them have their periodic revolutions around each other. Where two stars are found in a state of revolution about a common centre, they constitute what is called a *Binary System*. These, it must be remembered, are the *double* and *multiple* stars, which appear single to the naked eye. Sir W. Herschel noticed about fifty instances of changes in the angular position of double stars, and the revolution of some *sixteen* of these is considered certain. Their periods vary from 40 to 1200 years.

2. The star *Xi*, in the left hind paw of *Ursa Major*, is one of these stellar systems. The revolution of its component stars began to be noticed in 1781, since

which time they have made one complete revolution, and are now (1847) some eight years on the second. Of course, then, their periodic time is about fifty-eight years. Their angular motion is about 6° 24′ per year.

Dr. Dick supposes these stars to be some 200,000,000,000 miles apart; and upon the supposition that the smaller revolves around the latter, computes its velocity to be not less than 2,471,000 miles every hour. This would be 85 times the velocity of Jupiter, and 23 times the velocity of Mercury—the swiftest planet in the Solar System.

3. Fig. G on the map is a representation of another of these binary systems. It consists of the double star *Gamma*, in the Virgin. This star has been known as a double star for at least 130 years. The two stars are both of the third magnitude, and of a yellowish color. The largest star will be seen in the upper foci of the supposed orbit, and the arrows show the direction of the revolving star. At the first observation, by Bradley, in 1719, the smallest star was near the lower arrow, as represented. In 1756 it occupied a very different position, as the drawing shows, and so on to 1844, as represented on the map.

The period assigned to this system by Dr. Herschel is 629 years. The late E. P. Mason, of Yale College, estimated its period at 171 years: more recent observations and estimates by Mädler, give a period of 145 years.

4. Fig. H is a view of another of these systems of revolving stars, namely, the double star *p*, or 70 of the Serpent-bearer. In 1780 the smaller star was seen on the right, just above the lower arrow. In 1804 it was near that date on the map; in 1822, it was nearly opposite the first position, and so on to 1843.

The periodic time of the revolving star is about 93 years. In the course of its revolution the two stars sometimes appear separated, sometimes very near together, and at other times as one star. They are of the 5th and 6th magnitudes, and of a yellowish hue.

The following table shows the periodic times, &c., of these Binary Systems, so far as known. It is copied from

Herschel's Treatise, and corrected where more recent observations have shown it to be erroneous.

Names.	Period in years.	Major axis of the orbit.	Eccentricity.
η Coronæ,	43.40	———	———
ζ Cancri,	55.00	———	———
ξ Ursæ Majoris,	58.26	7″.714	0.4164
70 Ophiuchi,	93.00	8.784	0.4667
61 Cygni,	452.00	24.000	0.8335
γ Virginis,	252.66	16.172	0.7582
Castor,	286.00	7.358	0.6112
σ Coronæ,	145.00	30.860	———
γ Leonis,	1200.00	———	———

5. The student should here be reminded that these are not systems of planets revolving around suns, but of *sun revolving around sun*; and that their component stars may not only be as far apart as our sun and Sirius, but that they are probably each the centre of his own planetary system, like that which revolves around our central orb. Speaking of these systems, Dr. Dick observes:

"To some minds, not accustomed to deep reflection, it may appear a very trivial fact to behold a small and scarcely distinguishable point of light immediately adjacent to a larger star, and to be informed that this lucid point revolves around its larger attendant; but this phenomenon, minute and trivial as it may at first sight appear, proclaims the astonishing fact, that SUNS REVOLVE AROUND SUNS, AND SYSTEMS AROUND SYSTEMS. This is a comparatively new idea, derived from our late sidereal investigations, and forms one of the most sublime conceptions which the modern discoveries of astronomy have imparted. It undoubtedly conveys a very sublime idea, to contemplate such a globe as the planet Jupiter—a body thirteen hundred times larger than the earth—revolving around the sun, at the rate of twenty-nine thousand miles every hour; and the planet Saturn, with its rings and moons, revolving in a similar manner round this central orb in an orbit five thousand six hundred and ninety millions of miles in circumference. But how much more august and overpowering the conception of a sun revolving around another sun—of a sun encircled with a retinue of huge planetary bodies, all in rapid motion, revolving round a distant sun, over a circumference a hundred times larger than what has been now stated, and with a velocity perhaps a hundred times greater than that of either Jupiter or Saturn, and carrying all its planets, satellites, comets, or other globes along with it in its swift career! Such a sun, too, may as far exceed these planets in size as our sun transcends in magnitude either this earth or the planet Venus, the bulk of any one of which scarcely amounts to the thirteen-hundred-thousandth part of the solar orb which enlightens our day. The further we advance in our explorations of the distant regions of space, and the more minute and specific our investigations are, the more august and astonishing are the scenes which open to our view, and the more elevated do our conceptions become of the grandeur of that Almighty Being who 'marshalled all the starry hosts,' and of the *multiplicity* and *variety* of arrangements he has introduced into his vast creation. And this consideration ought to serve as an argument to every rational being, both in a scientific and a religious point of view, to stimulate him to a study of the operations of the Most High, who is 'wonderful in counsel and excellent in working,' and whose works in every part of his dominions adumbrate the glory of his perfections, and proclaim the depths of his wisdom and the greatness of his power."

6. Besides the revolutions of these double stars around each other, they are found to have a proper motion together in space, like that which our sun has around the great Central Sun. Upon this subject Sir John Herschel observes, that these stars not only revolve around each other, or about their common centre of gravity, but that they are also transferred, without parting company, by a progressive motion common to both, towards some determinate region.

"For example, the two stars of 61 Cygni, which are nearly equal, have remained constantly at the same, or very nearly the same distance, of 15″, for at least fifty years past. Meanwhile they have shifted their local situation in the heavens, in this interval of time, through no less than 4′ 23″, the annual proper motion of each star being 5″.3; by which quantity (exceeding a third of their interval) this system is every year carried bodily along in some unknown path, by a motion which, for many centuries, must be regarded as uniform and rectilinear. Among stars not double, and no way differing from the rest in any other obvious particular, μ Cassiopeiæ is to be remarked as having the greatest proper motion of any yet ascertained, amounting to 3″.74 of annual displacement. And a great many others have been observed to be thus constantly carried away from their places by smaller, but not less unequivocal motions.

"Motions which require whole centuries to accumulate before they produce changes of arrangement, such as the naked eye can detect, though quite sufficient to destroy that idea of mathematical fixity which precludes speculation, are yet too trifling, as far as practical applications go, to induce a change of language, and lead us to speak of the stars in common parlance as otherwise than fixed. Too little is yet known of their amount and directions, to allow of any attempt at referring them to definite laws. It may, however, be stated generally, that their apparent directions are various, and seem to have no marked common tendency to one point more than to another of the heavens. It was, indeed, supposed by Sir William Herschel, that such a common tendency could be made out; and that, allowing for individual deviations, a general recess could be perceived in the principal stars, *from* that point occupied by the star ζ Herculis, *towards* a point diametrically opposite. This general tendency was referred by him to a motion of the sun and solar system in the opposite direction. No one, who reflects with due attention on the subject, will be inclined to deny the high probability, nay, certainty, that the sun *has* a proper motion in *some* direction; and the inevitable consequence of such a motion, unparticipated by the rest, must be a slow *average* apparent tendency of all the stars to the vanishing point of lines parallel to that direction, and to the region which he is leaving."*

7. As already stated in a previous lesson, many of the double, triple, and multiple stars are of *various colors*, beautifully contrasting with each other.

> " ———————— other suns, perhaps,
> With their attendant moons ————,
> Communicating male and female light,
> (Which two great sexes animate the world,)
> Stored in each orb, perhaps, with some that live."†

"In such instances, the larger star is usually of a ruddy or orange hue, while the smaller one appears blue or green, probably in virtue of that general law of optics, which provides that when the retina is under the influence of excitement by any bright-colored lights, feebler lights, which seen alone would produce no sensation but of whiteness, shall for the time appear colored with the tint complementary to that of the brighter. Thus, a yellow color predominating in the light of the brighter star, that of the less bright one in the same field of view will appear blue; while, if the tint of the brighter star verge to crimson, that of the other will exhibit a tendency to green—or even appear as a vivid green, under favorable circumstances. The former contrast is beautifully exhibited by ι Cancri—the latter by γ Andromedæ; both fine double stars. If, however, the colored star be much the less bright of the two, it will not materially affect the other. Thus, for instance, η Cassiopeiæ exhibits the beautiful combination of a large white star, and a small one of a rich ruddy purple. It is by no means, however, intended to say, that in all such cases one of the colors is a mere effect of contrast, and it may be easier suggested in words than conceived in imagination, what variety of illumination *two suns*—a red and a green, or a yellow and a blue one—must afford a planet circulating about either; and what charming contrasts and 'grateful vicissitudes'—a red and a green day, for instance, alternating with a white one and with darkness—might arise from the presence or absence of one or other, or both, above the horizon. Insulated stars of a red color, almost as deep as that of blood, occur in many parts of the heavens, but no green or blue star (of any decided hue) has, we believe, ever been noticed unassociated with a companion brighter than itself."*

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* Sir John Herschel's Treatise on Astronomy.
† Paradise Lost, viii., 148.

Lesson 126.

VARIABLE OR PERIODICAL STARS.

1. Variable stars are those which undergo a regular periodical increase and diminution of lustre, amounting, in some cases, to a complete extinction and revival.

These variations of brilliancy, to which some of the fixed stars are subject, are reckoned among the most remarkable of the celestial phenomena. Some of them pass through their successive changes with great rapidity, while in other cases their brilliancy is increased or diminished gradually for months. The time occupied by one of these stars, in passing through all their different phases, is called its *period*.

2. One of the most remarkable of these variable stars, is the star *Omicron*, or *Mira* in the *Whale*. Its period is about 332 days, during which time it varies from a star of the second magnitude, to complete invisibility. It appears about twelve times in eleven years—remains at its greatest brightness about a fortnight, being then, on some occasions, equal to a large star of the second magnitude. It then decreases for about three months, when it disappears. In about five months it becomes visible again, and continues to increase during the remaining three months of its period.

Its increase of light is much more rapid than its decrease. It increases from the sixth to the second magnitude in 40 days—continues thus brilliant 26 days, and then fades to the sixth magnitude again in 66 days. Hence, it is above the sixth magnitude for 132 days, and below 200 days of its period.

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* Sir John Herschel's Treatise on Astronomy.

3. Another remarkable periodic star is that called *Algol*, in the constellation *Perseus*. It is usually visible as a star of the second magnitude, and such it continues for the space of 2 days 14 hours, when it suddenly begins to diminish in splendor, and in about 3½ hours it is reduced to the fourth magnitude. It then begins again to increase, and in 3½ hours more is restored to its usual brightness, going through all its changes in 2 days 20 hours and 48 minutes, or thereabouts. Through all its successive changes, this star shines with a white light, while the color of all the other variable stars is red.

4. The *cause* of these periodic variations in the brightness of some of the stars is not known. Some suppose them to be occasioned by opaque bodies revolving around them, and cutting off a portion of their light from us. Speaking of the sudden obscuration of *Algol*, mentioned above, Dr. Herschel remarks, that it indicates a high degree of activity in regions where, but for such evidences, we might conclude all lifeless. "I am disposed," says Dr. Dick, "to consider it as highly probable, that the interposition of the opaque bodies of large planets revolving around such stars, may, in some cases, account for the phenomena. It is true, that the planets connected with the Solar System are so small, in comparison of the sun, that their interposition between that orb and a spectator at an immense distance, would produce no sensible effect. But we have no reason to conclude, that in all other systems the planets are formed in the same proportions to their central orbs as ours; but, from the variety we perceive in every part of nature, both in heaven and earth, we have reason to conclude that every system of the universe is, in some respects, different from another. There is no improbability in admitting, that the planets which revolve round some of the stars, may be so large as to bear a considerable proportion

(perhaps one-half or one-third) to the diameters of the orbs around which they revolve; in which case, if the plane of their orbit lay nearly in a line of our own vision, they would, in certain parts of their revolutions, interpose between our eye and the stars, so as to hide for a time a portion of their surfaces from our view while in that part of their orbits which is next to the earth."

With reference to the obscuration and period of *Algol*, Professor Olmsted observes, that the periodic time of an opaque revolving body, sufficiently large, which would produce a similar temporary obscuration of the sun, seen from a fixed star, would be less than fourteen hours.

Others again are of opinion that those distant suns have one luminous and one dark or clouded hemisphere, and that their variations may thus result from a revolution upon their axes, by which they would present us alternately with their full and their diminished lustre.

Another theory is, that these stars are moving with inconceivable velocity in an immensely elliptical orbit, the longer axis of which is nearly in a direction to the eye; and the shorter axis of which would be imperceptible from our system. In such case the star would appear alternately to approach and recede, now looking in upon our quarter of the universe, as it were, for a few days, and then rushing back into immensity, to be seen no more by human eyes during the lapse of years or of ages.

"Whatever may be the *cause*," says Mr. Abbott, "the fact of these variations is perfectly established, and the contemplation of the stupendous changes which must be occurring in those distant orbs, overwhelms the mind with amazement. Worlds vastly larger than our sun suddenly appear, and as suddenly disappear—now they blaze forth with most resplendent brilliancy, and again they fade away—and often are apparently blotted from existence. These worlds are unquestionably thronged with myriads of inhabitants; and the phenomenon which to us appears but as the waxing or waning lustre of a twinkling star, may, to the dwellers on these orbs, be evolutions of grandeur, such as no earthly imagination has ever conceived. But these scenes, now veiled from human eyes, will doubtless all be revealed, when the Christian shall ascend on an angel's wing to the angel's home."

Lesson 127.

TEMPORARY STARS.

1. Temporary stars are those which have appeared from time to time, in different parts of the heavens, blazing forth with extraordinary lustre, and after remaining for a while apparently immoveable, died away, and left no traces of their existence behind. Some writers class them among the Periodical Stars, while others notice them under the head of "New and Lost Stars."

2. A star of this kind, which appeared in the year 125 B. C., led Hipparchus to draw up a catalogue of the stars, the earliest on record. In A. D. 389, a similar star appeared near the largest star in the Eagle, which, after remaining for three weeks as bright as Venus, disappeared entirely from view.

3. On the 11th of November, 1572, Tycho Brahe, a celebrated Danish astronomer, was returning in the evening from his laboratory to his dwelling-house, when he was surprised to find a group of country-people gazing upon a star which he was sure did not exist half an hour before. It was then as bright as Sirius, and continued to increase till it surpassed Jupiter in brightness, and was visible at noonday. In December of the same year it began to diminish, and in March, 1574, had entirely disappeared.

This remarkable star was in the constellation *Cassiopeia*, about 5° northeast of the star *Caph*. The place where it once shone is now a dark void!

This star was observed for about sixteen months, and during the time of its visibility its color exhibited all the different shades of a prodigious flame—"first it was of a dazzling white, then of a reddish yellow, and lastly of an ashy paleness, in which its light expired." "It is impossible," says Mrs. Sumerville, "to imagine any thing more tremendous than a conflagration that could be visible at such a distance."

In reference to the same phenomenon, Dr. Dick observes, that "the splendor concentrated in that point of the heavens where the star appeared, must have been, in reality, more than equal to the blaze of twelve hundred thousand worlds such as ours, were they all collected into one mass, and all at once wrapped in flames. Nay, it is not improbable, that were a globe as large as would fill the whole circumference of the earth's annual orbit, to be lighted up with a splendor similar to that of the sun, it would scarcely surpass in brilliancy and splendor the star to which we refer."

The same writer observes, that "within the last century, no less than thirteen stars in different constellations seem to have totally perished, and ten new ones to have been created."

REV. PROFESSOR VINCE, who has been characterized as "one of the most learned and pious astronomers of the age," advances the opinion that "the disappearance of some stars may be the destruction of that system at the time appointed by the DEITY for the probation of its inhabitants; and the appearance of new stars may be the formation of new systems for new races of beings then called into existence to adorn the works of their Creator."

LA PLACE, whose opinion upon such subjects is always entitled to consideration, says: "As to these stars which suddenly shine forth with a very vivid light, and then immediately disappear, it is extremely probable that great conflagrations, produced by extraordinary causes, take place on their surface. This conjecture is confirmed by their change of color, which is analogous to that presented to us on the earth by those bodies which are set on fire and then gradually extinguished."

DR. GOODE, author of the *Book of Nature*, &c., seems to have entertained an opinion similar to those already expressed. "Worlds and systems of worlds," says he, "are not only perpetually creating, but also perpetually disappearing. It is an extraordinary fact, that within the period of the last century, not less than *thirteen stars*, in different constellations, seem to have totally perished, and *ten new ones* to have been created. In many instances it is unquestionable, that the stars themselves, the supposed habitations of other kinds or orders of intelligent beings, together with the different planets by which it is probable they were surrounded, have utterly vanished; and the spots they occupied in the heavens have become blanks. What has befallen other systems, will assuredly befall our own. Of the *time* and *manner* we know nothing, but the fact is incontrovertible; it is foretold by revelation; it is inscribed in the heavens; it is felt through the earth; such is the awful and daily text. What then ought to be the comment?"

Lesson 128.

FALLING OR SHOOTING STARS.

The subject of shooting stars is here introduced, not because it properly belongs here, by the laws of philosophical classification, but because the juvenile student will be more apt to look for it in this connection than in any other part of the work. We must say but little, however, as its full discussion falls not within the compass of our design.

1. Falling or shooting stars are not properly *stars*, of any kind, but *meteors*, within a short distance of the earth. A meteor is a fiery or luminous body flying through the atmosphere.

2. Although the number of shooting stars observable in a single night is usually small, there have been instances in which they fell in such numbers as to be denominated *Meteoric Showers*. One of these occurred November 13th, 1833. On that morning, says Professor Olmsted, from two o'clock until broad daylight, the sky being perfectly serene and cloudless, the whole heavens were lighted with a magnificent display of celestial fireworks. At times the air was filled with streaks of light,

occasioned by fiery particles darting down so swiftly as to leave the impression of their light on the eye, (like a match ignited and whirled before the face,) and drifting to the northwest like flakes of snow driven by the wind; while, at short intervals, balls of fire, varying in size from minute points to bodies larger than Jupiter and Venus, and in a few instances as large as a full moon, descended more slowly along the arch of the sky, often leaving after them long trains of light, which were, in some instances, variegated with different prismatic colors.*

3. Of the *nature* of these meteors very little is known. They are supposed to descend from some point beyond the limits of our atmosphere, and to be ignited by their rapid motion, as they come in contact with it. They explode, and are resolved into small clouds, it is thought, at the height of about thirty miles above the earth.

Professor Olmsted thinks they are caused by some rare body like the tail of a comet, or the zodiacal light, falling in the way of the earth in her annual journey around the sun.

CHAPTER III.

OF CLUSTERS OF STARS, AND NEBULÆ.

Lesson 129.

OF CLUSTERS OF STARS.

(Map 16.)

1. In surveying the concave of the heavens in a clear night, we observe here and there groups of stars, forming bright patches, as if drawn together by some cause other than casual distribution. Such are the *Pleiades* and *Hyades* in Taurus, the former of which

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* Introduction to Astronomy, p. 282.

may be seen at I, on the map. These are called *Clusters of Stars*. The constellation *Coma Berenices* is another such group, more diffused, and consisting of much larger stars. The luminous spot called the *Bee Hive*, in Cancer, is somewhat similar, but less definite, and requires a moderate telescope to resolve it into stars. In the sword-handle of Perseus, is another such spot or cluster, which requires a rather better telescope to resolve it into distinct stars.

2. There is a great number of these objects, which have been mistaken for comets, as through telescopes of moderate power they appear like the comet of 1585, Map 15, or like small round, or oval, nebulous specks. Sir John Herschel observes that Messier has given a list of 103 objects of this sort, with which all who search for comets ought to be familiar, to avoid being misled by their similarity of appearance. That they are not comets, however, is evident from their fixedness in the heavens, and from the fact that when we come to examine them with instruments of great power, they are perceived to consist entirely of stars, crowded together so as to occupy almost a definite outline, and to run up to a blaze of light in the centre, where their condensation is usually the greatest.

3. Many of these clusters are of an exactly round figure, and convey the complete idea of a globular space filled full of stars, insulated in the heavens, and constituting in itself a family or society apart from the rest, and subject only to its own internal laws.

4. It would be a vain effort to attempt to count the stars in one of these globular clusters. They are not to be reckoned by hundreds; and on a rough calculation, grounded on the apparent intervals between them at the borders, and the angular diameter of the whole group, it would appear that many clusters of this description must contain at least from ten to twenty thousand stars, compacted and wedged together in a round space, whose angular diameter does not exceed eight or ten minutes, or an area equal to a tenth part of that covered by the moon.

5. Some of these clusters are of an irregular figure, as may be seen at J, on the map. These are generally less rich in stars, and especially less condensed towards the centre. They are also less definite in point of outline. In some of them the stars are nearly all of a size, in others, extremely different. It is no uncommon thing to find a very red star, much brighter than the rest, occupying a conspicuous situation in them.

6. It is by no means improbable that the individual stars of these clusters are suns like our own, the centres of so many distinct systems; and that their mutual distances are equal to those which separate our sun from the nearest fixed stars. Besides, the round figure of some of these groups seems to indicate the existence of some general bond of union in the nature of an attractive force.*

7. Figure J on the map, is a representation of the cluster in Coma Berenices already referred to; and Figure K is a magnificent cluster in Capricornus, containing more than a thousand fixed stars.

A cluster of stars, numbering over 1,000, has recently been announced as discovered by Professor Mitchel, of the Cincinnati Observatory.

Lesson 130.

OF NEBULÆ.

(Map 16.)

1. The term NEBULÆ is applied to those clusters of stars that are so distant as to appear only like a faint cloud or haze of light. In this sense some of the clusters heretofore described may be classed as nebulæ, and indeed it may be said of all the various kinds of nebulæ, that it is impossible to say where one species ends and another begins.

2. RESOLVABLE NEBULÆ are those clusters the light of whose individual stars is blended together, when seen

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* Herschel's Treatise.

through a common telescope, but which, when viewed through glasses of sufficient power, can be resolved into distinct stars.

3. IRRESOLVABLE NEBULÆ are those nebulous spots which were formerly supposed to consist of vast fields of matter in a high state of rarefication, and not of distinct stars. But it is exceedingly doubtful whether any nebulæ exist which could not be resolved into stars, had we telescopes of sufficient power. The following remarks, taken from a lecture recently delivered in Dublin, by Dr. Scoresby, in relation to the powers of Lord Rosse's mammoth telescope, will reflect light upon the subject under consideration. "About the close of last year, the Earl of Rosse succeeded in getting his great telescope into complete operation, and during the first month of his observations on fifty of the unresolvable nebulæ, he succeeded in ascertaining that forty-three of them were already resolvable into masses of stars. Thus is confirmed the opinion, that we have only to increase the powers of the instrument to resolve all the nebulæ into stars, and the grand nebular hypothesis of La Place into a splendid astronomical dream."

In a more recent communication Dr. Scoresby remarks, that the nebulæ already observed were between one and two hundred, which was doing well considering the observations had often been obstructed by the cloudy nights. Although this great telescope has been erected nearly two years, it has not been in complete operation more than six or seven months, and already the nebulæ, not before fully examined, have been discovered to be a collection of suns.

From these recent observations it is probable that all the nebulæ might be resolved into distinct stars if we had telescopes of sufficient power, and that such an object as an irresolvable nebula does not in reality exist.

While upon the subject of the nebulæ, as viewed by Lord Rosse, we must not omit to notice the extraordinary spiral nebula, recently discovered by the aid of his mammoth telescope. The following is the announcement of the discovery, as given in the English journals:

EXTRAORDINARY SPIRAL NEBULA DISCOVERED BY LORD ROSSE.

The Spiral Nebula is situated in the Dog's Ear, and although, by the common consent of astronomers, it was considered a mighty cluster of stars, it was not until Lord Rosse had seen it by the aid of his six-feet mirror that its resolution into stars was effected. This wonderful nebula bears closely on a problem relating to the structure of our own galaxy, the Milky Way. However strong the sympathies pervading all that strange system, it is cognizable by us, in the mean time, only as a collection of separate masses. Nor can we err in so deeming it, through ignorance of its real, as compared with its apparent structure, inasmuch as it is the manifest tendency of the telescope to deprive these remote objects of apparent uniformity, and endow them with a constitution more and more discreet. Now, these parts are, by themselves, somewhat intelligible. The central spherical group has the form in which gravity would sustain any mass of stars; and most of the other segregated portions also can be conceived as partial schemes internally harmonious, or arranged in obedience to their internal sympathies. But the feature the most remarkable for us is the character of the two principal lines of the scroll, or those two leading branches of that Milky Way where the stars of the group appear mainly distributed. It seems as if these beds of orbs were literally dissolving into fragments, which, in fact, is only a repetition of the most conspicuous characteristic of the zone encircling our own galaxy; for the bright circuit of our Milky Way is no regular belt, but, on the contrary, a succession of clusters, probably self-harmonious, stretching along its whole course, and separated by lines or patches more or less obscure.

Nothing can be more memorable than the conversion of these dim streaks of light into burning and rolling orbs: even a feat so grand and triumphant, in regard of the science and art of man, has an attraction infinitely less than the transforming of a shape apparently simple, into one so strange and complex that there is nothing to which we can liken it, save a scroll gradually unwinding, or the evolutions of a gigantic shell! How passing marvellous is this universe! And unquestionably that form would seem stranger still, if, rising farther above the imperfections of human knowledge, we could see it as it really is; if, plunging into its bosom and penetrating to its farther boundaries, we could develop the structure of its still obscure nebulosities, which doubtless are streams and masses of gorgeous related stars!

Figure L on the map is a representation of the great nebula in Andromeda, formerly considered as irresolvable. It resembles a comet, and may be seen under favorable circumstances by the naked eye, like a small faint cloud. The stars seen within its limits are supposed to be *beyond* it, and consequently seen through it.

4. Nebulæ are again distinguished as *Single* and DOUBLE NEBULÆ. The former consist of one cluster standing alone, while in the latter case two or more seem to be united, or in a state of near proximity, as in Figure M. Of the Double Nebulæ there is almost every possible variety of form and proportionate magnitude. The specimen given is a representation of the double nebulæ in the Greyhound.

5. Figure N is a representation of what are called HOLLOW NEBULÆ. This specimen may be found in the constellation Sagittarius.

6. STELLAR NEBULÆ, or *Nebulous Stars*, are such as present the appearance of a thin cloud with a bright star in or near the centre. They are round or oval-shaped, and look like a star with a burr around it, or a candle shining through horn. Figures O and P on the map are specimens of this class. O is in Cancer, and P in Gemini.

7. The *Sun* is considered by astronomers as belonging to this class of nebulous stars, and the *Zodiacal Light*, of which we have spoken in Lesson 108, has been regarded as of the nature of the gaseous matter with which the nebulous stars are surrounded. It is supposed that if we were as far from the sun as we are from the Stellar

Nebulæ, he would appear to us only as a small and nebulous star!

8. Planetary Nebulæ, says Dr. Herschel, are very extraordinary objects. They have, as their name imports, exactly the appearance of planets; round or slightly oval discs, in some instances quite sharply terminated, in others a little hazy at the borders, and of a light exactly equable or only a very little mottled, which, in some of them, approaches in vividness to that of the actual planets. Whatever be their nature, they must be of enormous magnitude. Granting these objects to be equally distant from us with the stars, their real dimensions must be such as would fill, on the lowest computation, the whole orbit of Herschel.

Fig. Q on the map, is intended as a specimen of Planetary Nebulæ, though, it must be confessed, it is not easy to get up a very striking resemblance.

9. Annular Nebulæ also exist, but are seldom to be met with. The most conspicuous of this class is to be found exactly half-way between *Beta* and *Gamma*, in the Lyre, and may be seen with a telescope of moderate power. It is small, and particularly well defined, so as in fact to have much more the appearance of a flat oval solid ring than of a nebula. The space within the ring is filled with a faint hazy light, uniformly spread over it, like a fine gauze stretched over a hoop.*

10. Figure R is a representation of a very remarkable nebula in the head of the Greyhound, about six degrees below *Mizar*, the middle star in the tail of the Great Bear. It consists of a large and bright globular nebula surrounded by a double ring, at a considerable distance from the globe, or rather a single ring divided through about two-fifths of its circumference, and having one portion turned up, as it were, out of the plane of the rest. A faint nebulous atmosphere, and a small round nebula near it, like a satellite, completes the figure.

11. Figure S is another remarkable nebula in the constellation of the Fox. The two round spots about the

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* Sir J. Herschel.

foci of the ellipse or oval, exhibit but a faint and dusky light, while the portions about the ends of the shorter axis are remarkably bright and uniform.

12. Figure T represents a wonderful nebula in the Milky Way. Its form is fantastic, and it has several openings, through which, as through a window, we seem to get a glimpse of other heavens, and brighter regions beyond.

13. The *number* of nebulous bodies is unknown, perhaps we should say innumerable. They are especially abundant in the *Galaxy* or Milky Way. Sir W. Herschel arranged a catalogue showing the places of *two thousand* of these objects. They are of all shapes and sizes, and of all degrees of brightness, from the faintest milky appearance to the light of a fixed star.

14. *Star Dust* is a name given to those exceedingly faint nebulous patches that appear to be scattered about at random in the far-distant heavens. They have no definite boundary, and are well represented by the *gray* portions of the map, *between* the various specimens of nebulæ. The map is printed light or gray on purpose to furnish specimens of Star Dust, or of nebulæ so remote as to be barely visible through the best telescopes. This class of nebulous appearances seems to lie in the background, far beyond others that are more distinctly visible.

By placing the learner at a proper distance from the map, the idea we wish to convey will be readily understood.

15. This map may be used to very good advantage to illustrate the uses and powers of the telescope, in resolving nebulæ into stars. Place the pupil at the distance of from fifteen to twenty feet, according to the strength of the light, so that he will see the clusters J and K only as faint cloudy patches. Let him then make what he may call a telescope of low power, by rolling up a sheet of paper, and looking through the tube thus formed. Shutting the surrounding light from his eye will enable him to see the nebulous spots far more distinctly. Then, instead of a telescope of higher power, let him approach half way to the map, and look again

through his paper tube. If the light is good, J and K will be mostly resolved into stars. By approaching still nearer, more stars will be seen where it appeared nebulous before, and at length the *Star Dust* will be seen lying beyond the more distinct nebulæ, in remote regions of space.

It must not be supposed, however, that barely shutting the surrounding light from the eye is the principle upon which the telescope reveals objects otherwise invisible; the object in these exercises is merely to show that as the nearer we are to an object the more distinct the vision, so the better the telescope (an instrument which seems to bring objects towards us) the more perfect the view we have of the different kinds of nebulæ, and the more likely they are to be resolved into distinct stars.

16. The nebulæ, says Sir John Herschel, furnish in every point of view an inexhaustible field of speculation and conjecture. That by far a larger share of them consist of stars, there can be little doubt; and in the interminable range of system upon system, and firmament upon firmament, which we thus catch a glimpse of, the imagination is bewildered and lost.

17. The *Milky Way* is generally regarded by astronomers as only a specimen of nebulæ, of which our sun is one of the stars. This zone of small stars (for such it actually is) extends quite around the Solar System, as the nebulous circle of Figure R, on the map, extends around the large star in the centre. Like that circle, also, the Milky Way is divided through some part of its circuit, and has various branches and irregularities.

The vast apparent *extent* of the Galaxy, as compared with other nebulæ, is supposed to be justly attributable to its comparative *nearness*. Were we as far from the Solar System as we are from the nebulæ in the Lyre, Fig. R, the Milky Way would doubtless appear as an *Annular Nebula* no larger than that. It may therefore with propriety be called "the Great Nebula of the Solar System."

The general conclusions of Mädler respecting the constitution of the whole system of the fixed stars, exclusive of the distant nebulæ, are the following:—He believes that the middle is indicated by a very rich group, (the Pleiades,) containing many considerable individual bodies, though at immense distances from us. Round this he supposes that there is a zone, proportionally poor in stars, and then a broad, rich, ring-formed layer, followed by an interval comparatively devoid of stars, and afterwards by another annular and starry space, perhaps with several alternations of the same kind, the two outmost rings composing the two parts of the Milky Way, which are confounded with each other by perspective in the portions most distant from ourselves.

But what an idea is here conveyed to the mind of the almost boundless extent of the Universe! Sir W. Herschel estimated that 50,000 stars passed the field of his telescope, in the Milky Way, in a single hour! And yet the space thus examined was hardly a point in this great zone of the "sun-strown firmament." The mutual distances of these innumerable orbs are probably not less than the distance from our sun to the nearest fixed stars, while they are each the centre of a distinct system of worlds, to which they dispense light and heat.

Were the Universe limited to the Great Solar Nebula, it would be impossible to conceive of its almost infinite dimensions; but when we reflect that this vast and glowing zone of suns is but one of thousands of such assemblages, which, from their remoteness, appear only as fleecy clouds hovering over the frontiers of space, we are absolutely overwhelmed and lost in the mighty abyss of being!

And here we may leave the reader to his own reflections. While unnumbered worlds and systems of worlds glow before his vision in the distant heavens, peopling, as it were, every portion of the mighty void, let it not be forgotten that as productions of the great Architect "these are but parts of his ways." While he upholds them all "by the word of his power," and presides over them as the GREAT KING, the falling sparrow attracts his notice, and the very hairs of our heads are numbered. And while we behold his Wisdom, Power, and Goodness so gloriously inscribed in the heavens, let us learn to be humble and obedient, to love and serve our Maker here, that we may be prepared for the more extended scenes of another life, and for the society of the wise and good in a world to come.

APPENDIX.

EXPLANATION OF ASTRONOMICAL TERMS.*

Aberration, an apparent change of place in the fixed stars, which arises from the motion of the earth combined with the motion of light.

Achernar, a fixed star of the first magnitude, in the constellation *Eridanus*, R. A. 1 hour 31 minutes.—Dec. 58 degrees, 16½ minutes.

Achromatic, colorless, remedying aberrations of color.

Achronical rising or setting of a planet, or star, is when it rises at sunset, or sets at sunrise.

Aerolites, or air-stones, are semi-metallic substances, which are found to fall from the atmosphere in different countries. Some philosophers have imagined that they are the fragments of a planet that had been burst asunder.

Aldebaran, a fixed star of the first magnitude in the head of the constellation Taurus; sometimes called the *Bull's eye*.

Algol, a star in Medusa's head, which varies from the second to the fourth magnitude.

Alioth, a fixed star in the tail of the Great Bear.

Altair, a star of the first magnitude in Aquila.

Altitude, the height of the sun, moon, or stars above the horizon, reckoned in degrees and minutes, on a vertical circle.

Amphiscii, a name given to the inhabitants of the torrid zone, on account of their shadows falling at one time of the year towards the south, and at another time towards the north.

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* This Glossary is copied from English works lately reprinted in this country, and revised to adapt it to the capacity of the Juvenile Learner. The *language* of the definitions is, in some instances, different from that used in the preceding pages, and a few terms are inserted and defined that do not occur in any of the lessons. But these circumstances will rather enhance than depreciate its value, as they secure an agreeable variety where the meaning is the same; will stimulate the investigation of subjects not yet understood; and may lead to additional research in fields not yet explored.

Amplitude, an arc of the horizon, contained between the east or west point of the heavens, and the centre of the sun or a star, at the time of its rising or setting.

Andromeda, a female, a northern constellation, containing 66 stars.

Annulus, a ring.—*Annuli*, rings.—*Annular*, ring-like.

Anomalous, irregular, strange, out of rule.

Anomaly, (the true,) the distance of a planet in signs, degrees, &c., from that point of its orbit which is furthest from the sun. The mean anomaly is, that which would take place if the planet moved uniformly in the circumference of a circle.

Antinous, the Youth, a part of the constellation Aquila.

Antipodes, those inhabitants of the earth who live diametrically opposite to each other, or walk feet to feet, on opposite sides of the globe.

Antóeci, a name given to those inhabitants of the earth who live under the same meridian, and at equal distances from the equator, but on opposite sides of it.

Aphelion, that point in the orbit of a planet in which it is at its greatest distance from the sun.

Apogee, that point in which the sun, or a planet, is furthest distant from the earth.

Approximate, next, near, approaching.

Apsides, the two most remote points of a planet's orbit, otherwise termed its aphelion and perihelion. A line joining those points is, the line of the apsides.

Arcticus, a star of the first magnitude in the Great Bear.

Arcturus, a bright star of the first magnitude in the constellation Bootes.

Armiliary sphere, an instrument composed of the principal circles which are drawn on an artificial globe.

Ascii, the inhabitants of the torrid zone; so called, because the sun being twice a year in their zenith, their bodies at those times cast no shadow.

Aspect, situation of the stars with respect to one another, or the planets.

Asteroids, the eight planets lately discovered moving in eccentric circles between the orbits of Mars and Jupiter.

Astronomy, (from *Aster*, a star, and *Nomes*, a law,) the science which teaches the motion, magnitude, and distances of the heavenly bodies.

Attraction, that inherent principle of matter by which bodies mutually tend towards each other, or to the centre of the earth.

Axis, (*axes*, plural,) of the earth or of a planet; an imaginary line passing through the centre from one pole to another, round which they perform their diurnal rotation.

Azimuths, great circles which pass through the zenith and nadir, perpendicular to the horizon. The azimuth of a celestial body is an arc of the horizon contained between the east and west points, and a vertical circle passing through the centre of that object.

Bellatrix, a star in Orion.

Belts, zones surrounding the body of Jupiter and Saturn.

Betelguese, a star in Orion.

Binary, double, consisting of two.

Bissextile, (or leap year,) which happens every fourth year, and contains 366 days; one day being added to the month of February.

Capella, a star of the first magnitude in Auriga.

Cardinal points of the compass; the east, west, north, and south points.

Cardinal points of the ecliptic; the first points of the signs Aries, Cancer, Libra, and Capricorn.

Castor, one of the Twins, a star of the first magnitude in Gemini.

Centauri, the Centaur, (half man and half beast,) a southern constellation.

Centrifugal force, that force by which any revolving body endeavors to fly off from the centre of motion in a tangent to the circle it describes.

Centripetal force, the tendency which a body has to the centre of its revolution.

Circumpolar, signifying such stars as being near the pole, move around it. They set below the horizon in our latitude.

Colures, two imaginary circles, or meridians, one of which passes through the solstitial points Cancer and Capricorn, and the other through the equinoctial points Aries and Libra.

Comets, erratic bodies belonging to our system, which move round the sun in very eccentric orbits, distinguished by their fiery tails and nebulous aspects.

Cone, a body with a circular base declining to a point, like a sugar-loaf.

Conical, form of a cone.

Conjunction, is when two or more stars, or planets, are in the same part of the heavens.

Constellation, or Asterism, certain figures delineated in the heavens by the ancients, and also by the moderns, within which the principal stars are included for the purpose of better finding and describing them.

Constituents, parts composing and essential to the whole.

Cosmical rising or setting of a planet, or star, is when it rises with the sun in the morning, or sets with him in the evening.

Crystalline heavens, the solid spheres by means of which the ancients attempted to account for the apparent motions of the fixed stars.

Cusps, the points or horns of the moon or of a planet.

Cycle of the moon, a revolution of nineteen years, in which time the conjunction and lunar aspects are nearly the same as they were nineteen years before.

Day, (solar,) the time between two successive transits of the sun's centre over the same meridian, which always begins and ends at noon.

Day, (sidereal,) the time which elapses during the rotation of the earth from one star till it returns to the same star again, and consists of 23 hours, 56 minutes, 4 seconds.

Declination is the distance of any celestial object north or south from the equator, reckoned in degrees, minutes, &c., upon a circle which is perpendicular to it.

Degree, the 360th part of a circle, or the 30th part of a sign.

Diagram, figure or representation used for illustration.

Digit, the 12th part of the sun's diameter, which is used in the calculation of eclipses.

Disc of the sun or moon, is its round face, which, on account of the great distance of the object, appears flat.

Diurnal motion of the earth, its rotation on its axis.

Dorpat or *Dorpt*, a town of Riga, Russia, where a University and Observatory were established and liberally endowed in 1802.

Eccentricity, the distance between the centre of a planet's orbit, and the focus round which it revolves.

Eclipse, a deprivation of the light of the sun, by the interposition of the moon ; or of the light of the moon, by the interposition of the earth.

Ecliptic, a great circle in the heavens through which the sun apparently makes his annual revolution ; but which is in reality the earth's path round the sun. It makes an angle with the equator of 23 degrees, 28 minutes.

Elaborated, produced with labor, improved by successive operations.

Ellipticity, likeness to an oval.

Elongation, the angular distance of a planet from the sun, as it appears from the earth. It is applied only to the interior planets, Mercury and Venus.

Emersion, the reappearance of a celestial body after having been eclipsed.

Epoch, particular period of time, period from one date to another.

Equation of time, the difference between real and apparent time, or between that shown by a true clock and a sun-dial. It depends on the obliquity of the ecliptic, combined with the unequal motion of the earth in its orbit.

Equator, or a great circle of the earth which separates the northern from the southern hemisphere. When referred to the heavens, it is called the *Equinoctial*.

Equinoctial, or Celestial Equator, the imaginary circle in the heavens described by the sun in its daily revolution at the time of the equinoxes, or its apparent passage over the line, when days and nights are equal all over the earth; the centre of the ecliptic.

Equinoxes, two opposite points in Aries and Libra, where the ecliptic cuts the equinoctial. When the sun is in these points, the days and nights are equal to each other.

Evolution, unfolding or unrolling of any thing

Exterior planets, those which move at a further distance from the sun than the earth; as Mars, Jupiter, &c.

Foci of an ellipse, two points in the longest, or transverse axis, on each side of the centre; from each of which if any two lines be drawn to meet each other in the circumference, their sum will be equal to the transverse axis.

Galaxy, or the Milky Way, a luminous and irregular zone which encompasses the heavens, which is found to be composed of an immense number of stars.

Geocentric place of a planet, is that position which it has when seen from the earth.

Gibbous, a term used in reference to the enlightened part of the moon, from the first quarter to the full, and from the full to the third quarter.

Gravity or *Gravitation*, that force by which all masses of matter tend towards each other.

Halo, a luminous circle round the body of the sun or moon.

Heliacal rising of a star, is when it emerges from the sun's rays, and appears above the horizon before him in the morning.

Heliacal setting of a star, is when it is so hid in the sun's beams as not to be seen above the horizon after him in the evening.

Heliocentric place of a planet, is that in which it would appear to a spectator placed in the sun.

Hemisphere, the half of a globe or sphere.

Heteroscii, a name given to the inhabitants of the temperate zones, because their shadows at noon always fall one way.

Horizon, (the sensible,) a circle which separates the visible from the invisible hemisphere, and forms the boundary of our sight.

Horizon, (the rational,) a great circle which is parallel to the former, and whose poles are the zenith and the nadir.

Hour circles, the same as meridians—marking the hours.

Immersion, the moment when an eclipse begins, or when a planet enters into the shadow of the body that eclipses it.

Inclination, the angle which the orbit of one planet makes with that of another, or with the plane of the ecliptic.

Interior planets, those that move at a less distance from the sun than the earth, which are Mercury and Venus.

Irresolvable, incapable of being analyzed, defined, or perceived as distinct objects

Latitude of a place, its distance from the equator, reckoned in degrees and minutes upon the arc of a great circle.

Latitude of a star or planet, is its distance from the ecliptic, reckoned in degrees, &c., on the arc of a great circle.

Leonis, a star in the constellation Leo or Lion.

Lesser circles of the same sphere, those whose planes do not pass through the centre, and which divide the sphere into two unequal parts. *Great circles* of the equator, meridians, &c., divide the sphere into two equal parts.

Libration of the moon, an apparent irregularity in her motion on her axis by which we sometimes see more than the usual half of her disc.

Longitude of a place, its distance east or west from the first meridian, reckoned in degrees, &c., upon the equator.

Longitude of a star or planet, its distance from the first point of Aries, reckoned in degrees, &c., upon the ecliptic.

Luminary, a body giving light, a celestial body.

Lunar, relating to the moon.

Lunation, the time between one new moon and another; which is, on an average, 29 days, 12 hours, 44 minutes, 3 seconds.

Maculæ, dark spots which appear on the face of the sun; and *Faculæ* are bright spots sometimes seen on the solar disc.

Magellanic clouds, certain whitish appearances in the heavens, in the southern hemisphere, supposed to consist either of an immense number of stars or nebulæ.

Magnitudes. The stars are divided into six classes; the brightest are called stars of the first magnitude; the next in brightness, the second magnitude, &c.

Mean motion of a planet, that which would take place if it moved in a perfect circle, and equally every day.

Meridian, a great circle of the sphere which passes through the zenith and the poles, and is perpendicular to the horizon.

Meteors, transitory luminous bodies in the air or sky.

Micrometer, an instrument fitted to a telescope to measure very small angles; as the diameters of the planets, &c.

Microscopic, relating to the properties of the microscope, —an instrument for magnifying small bodies by an arrangement of glasses or lenses,—to be seen only with the microscope.

Milky Way, Via Lactea, or Galaxy, the broad white path or cloud, seen as such by the naked eye, and varying in width from 5 to 16 degrees, but found by the telescope to consist of innumerable stars, (8 or 10 millions at least,) and assemblages of nebulæ and clusters of stars, the mingling light of which evolve whiteness.

Mythological, relating to the fabulous, though sometimes beautiful stories and theories of the ancients.

Nadir, that point in the heavens directly opposite to the zenith, or immediately under our feet.

Nebulæ, luminous spots in the heavens, or clusters of small stars, discovered by the telescope.

Nocturnal arc, that space of the heavens which the sun apparently describes from the time of his setting to his rising.

Nodes, two points where the orbit of the moon, or of a planet, intersects the plane of the ecliptic.

Nucleus, a term used to denote the head of a comet.

Oblique ascension, an arc of the equinoctial contained between the first degree of Aries, and that point of it which rises with the centre of the sun or star.

Oblique sphere, that position of the globe in which either of the poles is elevated above the horizon any number of degrees less than ninety.

Observatory, a place or building fitted up and provided with proper instruments for observing celestial bodies.

Occultation is when a star or planet is hid from our sight by the interposition of the moon or some other planet.

Opposition, an aspect of the stars or planets when they are 180 degrees distant from each other, marked thus, ☍.

Orbit, the curve which a planet describes in its revolution round the sun.

Orrery, a machine to represent the motions of the planetary bodies, so named in honor of the Earl of Orrery.

Oscillatory, moving backward and forward, like a pendulum.

Parallax, the difference of the place of any celestial object as seen from the surface of the earth, and from its centre.

Parallax of the earth's annual orbit, the angle at any planet subtended by the distance between the earth and the sun.

Parallels of latitude, small circles of the sphere which are drawn parallel to the equator.

Penumbra, a faint shadow observed between the perfect shadow and the full light in an eclipse.

Perigee, that point of the solar and lunar orbit which is nearest the earth.

Perihelion, that point of the orbit of a planet nearest the sun.

Periscii, the inhabitants of the frigid zones, so named because their shadows go round them for six months, or fall towards opposite points of the compass.

Perturbation, disturbance, disorder, disquietude.

Phases, the different appearances of the illuminated parts of the moon or planets.

Phenomenon, any extraordinary appearance in the heavens, as a comet, &c.

Planetarium, an astronomical machine for showing the motions and other phenomena of the planets.

Planetary, relating to planets.

Pleiades, or the seven stars, an assemblage of stars in the constellation Taurus.

Polar circles, two small circles, 23½ degrees from the poles; the arctic in the north, and the antarctic in the south.

Pole star, a star of the second magnitude in the tail of the Little Bear; so called, because it is near the north pole.

Precession of the equinoxes, a slow motion of the two points where the equator intersects the ecliptic, which go backward about 50 seconds in a year.

Quadrant, the fourth part of a circle; or an instrument for measuring angles, and taking the altitudes of the sun and other heavenly bodies.

Quadrature, that position of the moon when distant 90 degrees from the sun; as in the first and third quarters.

Radius Vector, a line supposed to be drawn from the centre of any planet to the centre of the sun, which, moving with the planet, describes equal areas in equal times.

Refraction, the bending of the rays of light in passing through the atmosphere, by which the heavenly bodies appear more elevated than they really are.

Refrangible, capable of being bent or turned aside.

Regulus, a star of the first magnitude in the constellation Leo.

Resolvable, that which may be analyzed, brought together and explained or defined.

Retardation, hinderance, act of delaying.

Retrograde, an apparent motion of the planets in some parts of their orbits, when they seem to go backward, or contrary to the order of the signs.

Right ascension is that degree of the equator which comes to the meridian with the sun, moon, or star, reckoning from the first point of Aries.

Rotation, the motion of any heavenly body round its axis.

Satellites, secondary planets or moons, which revolve round the primary planets.

Selenography, a representation of the moon, with a description of her different spots and appearances.

Sextile, an aspect of the heavenly bodies, when they are 60 degrees distant from each other.

Sidereal, of or belonging to the stars.

Sign, the twelfth part of the ecliptic, or 30 degrees.

Sirius, "the Dog Star," one of the brightest in the heavens, is in the constellation Canis Major.

Solar, relating to the sun.

Solstitial points, the first degree of Cancer and Capricorn, at which the ecliptic touches the tropics.

Sphere, the concavity of the heavens in which the stars appear.

Sphericity, rotundity, roundness.

Spica, a star of the first magnitude in the constellation Virgo.

Star Dust, clusters of small stars appearing like sparkling sand.

Stellar, relating to stars.

System, a number of bodies revolving round a common centre, as the planets round the sun.

Syzigy, a term usually applied to the moon, when in opposition or in conjunction, or when at the new or full.

Telescope, an optical instrument for the purpose of viewing distant objects, particularly the sun, moon, planets, and stars. Telescopes produce their effects either by refraction through glasses, or reflection from speculums.

Telescopic stars, those stars which are only visible by means of telescopes. All stars beyond those of the sixth magnitude are reckoned telescopic stars.

Torrid zone, that part of the earth which is contained between the two tropics.

Trajectory a term applied to the orbit of a comet.

Transit of a planet denotes its passing over another planet or star, or across the disc of the sun.

Trine, an aspect of the planets when they are 120 degrees distant from each other.

Tropics, two circles parallel to the equator, and 23 degrees 28 minutes distant on each side of it. They are named Cancer on the north, and Capricorn on the south.

Vertical circles, the same as azimuth circles, or such as are drawn perpendicular to the horizon.

Prime vertical, is that azimuth circle which passes through the east and west points of the horizon.

Year, (the solar,) the time which the sun takes to pass from one tropic till it returns to the same again, and is 365 days, 5 hours, 48 minutes, 49 seconds.

Year, (sidereal,) the time which the sun takes to pass from any fixed star to the same again, and is 365 days, 6 hours, 9 minutes, 9 seconds.

Zenith, that point of the heavens immediately over head.

Zodiac, a zone surrounding the heavens, 16 degrees broad, in the middle of which is the ecliptic. The orbits of all the old planets are included in this zone.

Zodiacal, relating to the Zodiac, great circle of the sphere, signs, &c.

Zodiacal light, a brightness sometimes observed in the heavens, somewhat similar to the Milky Way.

Zone, a division of the sphere between two parallels of latitude. There are five zones; one torrid, two temperate, and two frigid.

QUESTIONS

ON THE

ELEMENTARY ASTRONOMY

BY H. MATTISON.

LESSON 1.—What do we understand by the term *science?* What is *astronomy?* How do the sun and moon compare with each other in their apparent *size?* How with the other heavenly bodies? What difference in their *light?* What said of their *change of position* with respect to each other? What said of the different *appearances* of the moon? What remark respecting the *horns* of the old and new moon? In what *direction* does the moon actually go; and how is it ascertained? What said of her *covering*, or *obscuring*, the stars? What of the *dark lines* or *figures* upon her face? What is an *eclipse?* Have you ever seen one? Was it of the *sun*, or *moon?* What said of the apparent *size* of the stars? What of their relative *positions?* What exceptions to their general apparent fixedness? What *irregularity* is observed in their motions? What said of the *morning* and *evening* star? Of the stars about the North Pole? Of the *change* of the *sun's position*, from winter to summer, &c.? May all the phenomena thus far enumerated be observed by the *naked eye*, or without telescopes? How did the *ancients* study astronomy? Of what is the science of astronomy composed, and how is it constituted?

2.—Where do we find the oldest records of astronomical science? What clusters of stars are there mentioned, and in what books? How does the Bible represent the earth as upheld? What Greek philosopher taught astronomy before Christ, and who in the second century after Christ? What was Ptolemy's theory called? Where did it locate the earth? Describe the Ptolemaic theory in detail, and illustrate by the map.

3.—Were there any special difficulties in the theory of Ptolemy? What is the *first* mentioned by your author? What is the *second?* What is the *third,* and how is it illustrated? What is the *fourth* and last difficulty named? What would be the hourly motion of the *sun* upon this theory? How swiftly would it require the nearest *fixed stars* to move? Was such an absurd theory ever generally believed? How long did the doctrines of Ptolemy prevail?

4.—Who originated the present generally received system of astronomy? About *what time?* What is this theory called, and why? How does this system account for the apparent daily motion of the sun, moon, &c., from east to west? Do we ever suppose objects to move that are at rest, simply because *we* are moving? Give an illustration. Where does the Copernican theory place the *sun?* What two motions does it attribute to the numerous worlds that surround him? What does the first of these motions produce, or cause? What the second? What map illustrates this theory? Where is the sun seen on the map? Where the planets, and fixed stars? What is meant by the *orbit* of a planet, and how represented on the map? In what direction do the planets move around the sun? How indicated on the map? What particular fact is referred to as evidence of the truth of the Copernican theory?

5.—What are the first grand divisions of the universe? What is meant by the *solar system?* What by the *sidereal heavens?* How is the former situated in respect to the latter? Which of these grand divisions is first considered by your author?

6.—From what does the solar system derive its name? What are the bodies of our system called, as a whole? How are the solar bodies first divided? How is the sun distinguished from the planets? The planets from the sun? What does the term planet *signify?* How are the planets *divided?* What are the *primaries?* Describe the *secondaries.* Point out each on the map. Which are the *interior* planets, and why? Which the *exterior?* What are the *asteroids?* What are *comets,* and how distinguished? Point out the different classes of solar bodies on the map.

7.—How many *primary planets* are there? What are their *names?* What are they generally named after? In heathen mythology, who was *Mercury,* and what does the astronomical sign of this planet represent? Who was *Venus,* and what is her sign? What two signs represent the *Earth?* Who was *Mars,* and what is his sign? Describe *Vesta,* and her sign; *Astrea,* and her sign; *Juno,* and her sign; *Ceres,* and her sign; *Pallas,* and her sign; *Jupiter,* and his sign. What is the origin of the sign of Jupiter? Describe *Saturn,* and his sign. From what did *Herschel* derive his name? What other names has he? What constitutes his sign? From whom does *Le Verrier* derive his name? Of what is his sign composed? What name did the Board of Longitude of Paris recommend for this planet? Can you make the signs of the different planets upon the black-board? [The class should here make and explain the different signs, in consecutive order.] Make the sign for *new, half-grown,* and *full moon.* The signs of the sun. What does the first represent? Find the several primary planets on the map. Where should *Le Verrier* be placed?

8.—What is the subject of this lesson? What is the *scale of distances* employed on the map? Give the distances of the several planets, commencing at the sun. What said of conceiving justly of such vast distances? At the rate of five hundred miles per hour, how long would it require for a body to pass from the sun to Mercury? How long from the sun to our globe? How long to reach Herschel? What illustration employed? How long would it take for a train of cars to pass from the sun to Mercury, at thirty miles per hour? To our globe? To Herschel? To Le Verrier? How illustrated by reference to Whitney's proposed railroad? If a train of cars had left the sun, at the creation of the world, to visit the orbit of Herschel, where would they be now? How much longer would it require to finish the journey? To reach the orbit of Le Verrier?

9.—What is the subject of this lesson? What is a *circle?* A *quadrant?* A *sextant?* A *sign?* A *degree?* A *minute?* A *second?* Illustrate these several divisions of a circle, by the map. How many degrees are there in a circle? Have all circles the same number of degrees? Make the signs for degrees, and minutes, and seconds. What is measurement by degrees, minutes, and seconds, called?

10.—Give examples of angular measurement, distances, diameters, altitudes, and velocities, from the map, Fig. 1. How does the *distance* of the observer from an object effect its apparent magnitude, &c.? How is this illustrated by Fig. 2?

11.—Upon the principles of the preceding lesson, how would the sun appear, viewed from *Mercury?* From *Venus?* From *Le Verrier?* From *Sirius?* What is the angular diameter of the sun, as viewed from our globe? What would it be from *Mercury?* From *Jupiter?* From *Herschel?* From *Le Verrier?* What idea of the *distance* to Le Verrier would arise from the diminutive appearance of the sun, if viewed from that point?

12.—What is the subject of this lesson? By what rule do we determine the relative amount of light received by bodies placed at unequal distances from their luminary? How is this rule illustrated by Fig. 4?

13.—By applying the rule of the preceding lessons to the planets, and supposing the light and heat of each to be proportionate, what would be the *relative light* and *heat* of Mercury, Venus, &c.? What, then, would be the average temperature of Mercury? Of Venus? Of Jupiter? Of Saturn? Of Herschel? Of Le Verrier? Is it certain that the light and heat are proportionate upon the several planets? What said of the *temperature* of *Mercury?* What of the temperature of *Jupiter, Saturn, Herschel,* and *Le Verrier?*

14.—What is the subject of this lesson? By what scale are the planets drawn on the map? Is the sun drawn upon the same scale? Why not? Give the *diameters* of the several planets, beginning at Mercury. Do the relative sizes on the map seem to *correspond* with these diameters? At forty thousand miles to an inch, what should be the diameter of Saturn, on the map, according to the table of magnitudes? What should be the diameter of the earth?

15.—Of what does this lesson treat? What is the scale of map 4? What is the actual diameter of the sun, in miles? At forty thousand miles of diameter to an inch, how large must he be drawn to correspond with the other planets? What is the *bulk* of Mercury, as compared with the earth? Of Venus? Of Mars? Of Jupiter? Of Saturn? Of Herschel, and Le Verrier? What is the bulk of the *sun*, as compared with our globe? What as compared with the whole solar system besides? How many globes like ours would it take, if laid side by side, to reach across the sun's diameter? What illustration of the sun's magnitude is drawn from the moon's orbit?

16.—What is the subject of this lesson? What is meant by *density?* Give examples of substances of different densities. Have all the planets the same density? Give the density of the several planets, as compared with the earth, and the substances with which they most nearly agree in weight.

17.—The subject of this lesson? What is meant by *gravitation?* What constitutes the *weight* of bodies? Upon what does the amount of weight depend? Do large bodies *always* attract more strongly than small ones? Why not? Do the planets differ in their attractive force? What would a body weighing one pound on the *earth*, weigh upon *Mercury?* Upon *Venus*, &c.? What upon the *sun?* What said of the attractive force of the *asteroids?* Is the attraction of the planets in proportion to their *bulk?* Why not?

18.—What is meant by the *periodic revolution* of a planet? What by its *periodic time?* Can you give the periodic times of the several planets? What constitutes a planet's *year?* Do all the planets move with the *same velocity?*

19.—What is the subject of this lesson? Can you give the hourly motion of the several planets?

20.—What is meant by the *centripetal force* of a planet? What by the *centrifugal?* What would be the result were the centripetal force *suspended?* What if the centrifugal? Why does Mercury revolve more rapidly in his orbit than any other planet? Why do the more distant planets move so slowly? What particular fact respecting the motions of the planets is mentioned as exhibiting the wisdom of God?

21.—Have the planets any revolution except around the sun? What is it called in the caption of this lesson? What natural phenomena are produced by the revolution of the planets upon their axes? Recite the time occupied in the diurnal revolutions of the several planets, so far as known. What do you observe as rather remarkable respecting the first four planets? What peculiarity in the time of *Jupiter* and *Saturn?* How many days have Jupiter and Saturn in one of our years? How many has Jupiter in one of *his* years? How many has Saturn in one of *his* years? How was it ascertained that the planets had a diurnal revolution? Has the motion of the planets on their axes any effect in modifying their *forms?*

22.—What effects would follow if the planets were *cubes* instead of *globes?* Are the planets exactly spherical in their forms? What is their true figure? Where is their diameter greatest? What causes this flattening or oblateness? What is the difference between the polar and equatorial diameter of the several planets?

23.—What is the *ecliptic?* Point out the ecliptic on the map. Why is the earth represented of different sizes? What said of her *phases, color,* &c.? What do the *arrows* set in her orbit indicate? What further illustration of the *ecliptic* is given by the author? Are the sun and earth always in the *plane* of the *ecliptic?*

24.—What are the *poles* of the earth? What the poles of the *ecliptic?* How illustrated by the pointer and map? Are the *ecliptic* and the *earth's equator* in the same plane? How, then, with their *poles?*

25.—How does the *ecliptic* lie with respect to the *earth's equator?* How does this affect the position of the *sun* at different seasons of the year? Does the plane of the equator pass the ecliptic *perpendicularly* or *obliquely?* What angle is included between them? What is this deviation of the ecliptic from the plane of the equator called? Can you illustrate this subject by the map?

26.—What is the *Zodiac?* How is it represented on the map? What portion of the heavens does the Zodiac include?

27.—The *subject* of this lesson? How is the Zodiac *divided?* How are these divisions shown on the map? What did the ancients imagine respecting the stars of each sign? What are the *names* of the twelve signs? Can you make their *symbols* on the black-board? What notion had the *ancient astrologists* respecting the signs? Are there any that still hold to this idea? Is it *correct?* What do they seem to understand by the word "*sign?*" What is its true meaning in Astronomy?

28.—Its subject? What does Figure 1 on the map represent? What is the plane of the ecliptic? [23] How many times must a planet pass through the ecliptic at each revolution? What are the points called where a planet cuts the ecliptic? How are the nodes distinguished? Can you make the astronomical sign for each? What is meant by the *line of the nodes?* Point it out on the map In the figure, where is the *Ascending* Node placed as respects the signs? Where the *descending?* Does the figure represent the actual position of the nodes of any planet's orbit?

29.—What is a *transit?* Which of the planets make transits over the sun's disc visible to us? Why do not the other planets? What planets would make transits if we were placed upon Herschel? Where must the planet making the transit be, at such time, in respect to the nodes of its orbit? How with the observer? Why do not the *interior* planets make transits at every conjunction with the sun? How could this be effected while their orbits do not coincide with the ecliptic? How are transits calculated? How often can the Earth and Mercury meet at the same node?

30.—Subject? In *what months* do all the transits of Mercury occur? Why is this? At which node do his *November* transits occur? His *May* transits? Do the transits in the table conform to the ratio laid down in Lesson 29? Did you ever see a transit? When does the next transit of Mercury occur?

31.—Subject? How many revolutions of Venus equal eight of the earth? Can you state any of the other periods in the table? Where does the *line of Venus' nodes* lie? When does the earth pass these points in the ecliptic? What fact follows from the last-named circumstance? When does Venus make the next transit? How many, yet to occur, are laid down in the table? Are those predicted to occur in accordance with the ratios given at the commencement of the lesson?

32.—Subject? What do you understand by an *eclipse?* [23] What are the *orbits* of the planets? [4] What does Fig. 1 on the map represent? Is any planet's orbit thus inclined? What does Fig. 2 represent? Where is the sun placed? What represents the *Ecliptic?* What are seen on the right and left? What do the plain lines represent? Where do you find the names of the planets, and where the amount of their inclination respectively? How much is the orbit of Mercury inclined? That of Venus? Earth? (Think, now.) Mars, &c.? What part of the map represents the *Zodiac?* Where do most of the planets' orbits lie, as respects the Zodiac? What exceptions? Hence sometimes called what? What two objects are seen near the middle of the figure? What difference in their direction? What fact is this designed to illustrate?

33.—Are the *equinoctial* and *ecliptic* in the *same plane?* At what angle do they intercept each other? What is *terrestrial latitude?* Is *celestial* latitude reckoned from the *equinoctial* or *celestial equator?* From what, then? What, then, is *celestial latitude?* What seeming contradiction follows from this fact?

34.—What is *longitude* on the earth? From *what point* in the heavens, and *how*, is celestial longitude reckoned? What is the map, as a whole, a representation of? How must it be placed to answer to the Zodiac in the heavens? Show me where you begin to reckon longitude on the map, and where you end. If Aries, for instance, were directly overhead, where would Libra be? What is the longitude of the Twins; the Lion; the Balance; the Goat, &c.?

35.—Subject? In what *signs* are the *nodes* of Mercury's orbit? *Where* and *how* is this illustrated? Which side of the ecliptic is considered as *above*, and which *below?* What, then, is it to *ascend* above, or *descend* below it? What do the *arrows* near the sun show? What the next pair? Why is not the longitude of both nodes laid down in astronomical tables? What example does your author cite? Can you give the *longitude* of the *ascending nodes* of the planets respectively?

36.—Subject? What is a *constellation?* Do the *signs* and *constellations* of the Zodiac bear the same names? Do the signs "govern" different parts of the human body, as stated in some almanacs? What are the *names* of the constellations of the Zodiac?

37.—Subject? What does Fig. 1, Map 5, represent? When the earth is in Libra where will the sun appear to be? As she passes around to Scorpio, what will the sun appear to do? Hence what does the sun seem to do once a year? How is this illustrated by Map 6? What is the earth's longitude on the 20th of March? What sign does the *sun* enter on that day? When does the sun enter the different signs? Does he *really move* around the ecliptic? What, then, gives him his apparent motion? Which are the *spring* signs, and why so called? Which the *summer?* The *autumnal?* The *winter?*

38.—Are there any stars above us in the daytime? Why do we not see them? If we could see them would they be the same that we now see in the night? What stars, then, are above us in the daytime? Are stars ever visible in the daytime? When? How? Why do the stars rise earlier and earlier every night from year to year? How do you illustrate this subject by the map? What other use do you make of this map?

39.—Subject? Why are the names of the *months* placed as they are on the map? Do the months and signs *agree in longitude?* Which is entered first, the new *sign* or the new *month?* What is the difference of time? How is this shown on the map?

40.—Subject? By what imaginary lines is the Zodiac divided? How distinguished on the map? What are the *equinoctial points* in the earth's orbit? Why so called? What is the *equinoctial?* When does the earth pass the equinoctial points? How are these points distinguished?

41.—Subject? Is this an easy or a difficult lesson? In what *signs* are the equinoctial points? What do you understand by the "*Precession of the Equinoxes?*" Is it an actual *precession* of the equinoxes, or a *recession?* Do the equinoctial points, then, *actually recede?* What is the amount of their annual motion? Are the equinoctial points fixed points, then? What, then, constitute the *vernal* and *autumnal equinoxes?* What constitutes a *natural* or *tropical year?* Is the equinox reached before the earth has made a complete periodic revolution? How much more time is requisite to complete a *sidereal* revolution? How long does it take the sun and equinoxes to fall back a whole degree? Do the *signs* recede like the equinoxes? Which way do they seem to move from the equinoxes? What does this motion require in regard to maps and celestial globes? How often does this recession of the equinoxes amount to 30°?

42.—Subject? How are the *solstitial points* represented on the map? When does the earth reach the *summer* solstice? Where does the *sun* seem to be then? When does the earth reach the winter solstice? Where is the sun then? What causes the *declination* of the sun north and south of the equinoctial?

43.—Subject? What are the *Colures?* How are they distinguished, and why? How are they compared to meridians? How do they divide the celestial sphere? How illustrated by hoops of wire? What is gained by knowing the place of the colures in the heavens?

44.—Subject? Upon what supposition has your author proceeded thus far, as respects the planets' orbits? What is their true figure? Where is this represented? Are the planetary orbits all alike in this respect? What bodies have orbits still more elliptical? Where is the sun found as respects the centre of these elongated orbits? Illustrate by the map. What is the point where the sun is found called?

45.—The subject? What is the *perihelion point* in a planet's orbit? What the *aphelion?* What do *perigee* and *apogee* mean in respect to the moon? Point out the *perihelion* and *aphelion* points in the earth's orbit, on the map. What is the *difference* between the *perihelion* and *aphelion* distance of a planet? What is meant by its *mean* distance? Which distance is given in Lesson 8? What do you understand by the *longitude of perihelions?* In *what longitude* is the *earth* nearest the sun? Can you point out upon Map 6 the perihelion points of the several planets, according to the *longitude* given in the table?

46.—What is the subject of this lesson? What is meant by the *eccentricity* of a planet's orbit? How illustrated by the map? What is the eccentricity of the orbit of Mercury? Of that of Venus? Of the Earth? If the sun is 1,618,000 miles one side of the *centre* of the earth's orbit, *how much nearer* the sun is the earth at *perihelion* than at *aphelion?* Which of the planetary orbits are the most elliptical? Which is the nearest a circle?

47.—Subject? How much is the *earth's axis* inclined to the *ecliptic?* Where is this illustrated? What other fact is illustrated by the same figure? When does the light of the sun extend to both poles? When have we the greatest amount of sunlight in the *northern* hemisphere? Is it *summer* or *winter* here, then? Where, on the map, is the earth at this time? Where is the earth at the time of the *winter* solstice? What has the sun appeared to do between the summer and winter solstices? What is thus produced by his seeming change of position? Are we nearest the sun in *summer*, or in *winter?* Why, then, is it not warmest in the northern hemisphere in *December?* How *may* the eccentricity of the earth's orbit affect the seasons?

48.—Subject? What do you understand by the sun's *declination?* When does he have *northern* declination? When *southern?* What is his declination at the time of the equinoxes? When is it greatest? What figures illustrate this subject? What does Fig. 2 show? What further illustration have we in Fig. 3? Point out the place of the sun at the time of the *winter solstice.* Where is he on the 20th of March? Where on the 23d of September? Where on the 21st of June? Is he directly overhead then? How many degrees does he lack of it, according to the figures? What is meant by the *zenith point?* From all this, what do we learn respecting *declination?*

49.—Subject? What do you understand by *right ascension?* What is the *equinoctial?* [40] Wherein does *celestial* latitude differ from *terrestrial?* What celestial measurements, then, answer to latitude and longitude on the earth? Could you understand and remember *declination* and *right ascension* better, if they were called celestial *latitude* and *longitude?* What does your author think of such a change of terms? · How many *degrees* of right ascension can there be? Wherein do *right ascension* and *celestial longitude* differ?

50.—What is the *ecliptic?* What are the *orbits* of the planets? What is the subject of lesson 32? What the subject of this lesson? What does your author say of this lesson? What represents portions of the planetary orbits on the map? How are their several *axes* shown? How their *equators?* Their *zones?* Upon what does the *extent* of the torrid zone of a planet depend? How does the sun's *declination* north and south of the equator, and *polar inclinations* agree? How does the torrid zone compare, in its extent, with the polar inclination of a planet? Do you now understand *how* the inclination of the axes of the planets affects the extent and character of their zones? What said of Mercury, the asteroids, Herschel, and Le Verrier?

51.—Upon what two causes do the seasons of the planets depend? What does the former determine? The latter? Illustrate by the map. Have you reviewed lesson 46? [See questions.] Do you still remember what is meant by the *obliquity* of the *ecliptic?* What do you understand by *declination?* What is the difference between the *ecliptic* and the *equinoctial?*

52.—Subject? How far are Venus' tropics from her equator? Has she a frigid zone? What said of the sun's declination upon Venus? Of her seasons? Can such seasons produce vegetation?

53.—Subject? What said of the polar inclination of Mars? Are his seasons, then, like ours? Why not? How many seasons has he? What is their length?

54.—Subject? What is the inclination of Jupiter's axis to the plane of his orbit? How does this affect his zones? What said of the sun's declination upon Jupiter? Of his temperate zones? His days and nights? His poles? What is his light and heat, as compared with our globe? His diameter? His *relative* magnitude? His figure? The time of his rotation upon his axis? His mean distance from the sun?

55.—Subject? What said of his polar inclination? What is his periodic time? What is the *number* and *length* of his seasons? What said of his polar regions? Where do the *rings* of Saturn lie? What is the time of their revolution? How crossed by the sun? How are the sides of the rings alternately enlightened? What said of the seasons on the sides of the rings? When will they be turned edgewise towards the earth? How will he be enlightened then? Where, in his orbit, will he then be? Where in seven and a half years after?

How will his rings then appear? What will the sun's declination then be from the planet's equinoctial? What will follow in seven and a half years more? When will his rings become invisible? Why can they not then be seen? When will they become visible again? Have we any further illustration of the seasons of Saturn, the structure of his rings, &c.? Have all the planets, then, their day and night, cold and heat, winter and summer, &c.?

56.—Subject? What is celestial longitude? [34] When are planets said to be in *conjunction?* How illustrated by the map? What planets have *two* conjunctions? What are they called? What is the difference? Illustrate by map. What difference in the *distance* of Venus *from the earth* at her two conjunctions? How explained by the map? What conjunction has the *exterior* planets? Why not an *inferior* conjunction? When is a planet said to be in *opposition?* What said of the rising and setting of planets in conjunction and opposition? Make the astronomical signs for conjunction and opposition upon the black-board. As Venus, passing eastward, forms a conjunction with the sun, how does she usually pass him? How is this accounted for? When does Venus pass over the sun's disc? How is such transit illustrated by the map?

57.—Subject? What is a *sidereal* revolution of a planet? What a *synodic?* What is the difference? How illustrated by the map? How long from one inferior conjunction of Venus to another? Why do the synodic periods of Jupiter, Saturn, &c., vary so little from the periodic time of the earth?

60.—Subject? What difference between the *direct* and *retrograde* motions of planets? Can you explain the cause of this seeming retrogression, and illustrate by the map?

61.—Can you explain the retrogression of the exterior planets by the map? What is meant by the "*arc of retrogradation?*" Why have the more distant planets the smallest arc? Why so long in retrograding so short a distance?

62.—Subject? When is Venus *east*, and when *west* of the sun? When is she *morning star*, and why? When *evening star*, and why? What did the ancients think of this star, and how named? How long is Venus alternately morning and evening star? What is meant by her *greatest elongation* east and west? Can you illustrate the different points in this lesson by the map?

63.—Subject? What is meant by "*phases?*" Why do Mercury and Venus present different phases? Illustrate by map. When does Venus appear largest, and why?

64.—Subject? What three facts does your author state respecting the primary planets? Have any spots ever been seen upon Mercury? By whom? What else does he say he saw and measured? What is the telescopic *color* of Mercury? Have you carefully noticed the ten views of Venus shown on the map? What do you suppose these spots to be? What said of the *mountains* of Venus? What of her *atmosphere?* What of her *color?* What does Fig. 13 on the map represent? Where is the observer supposed to be, and how assisted in his vision? Why would the land appear brightest? From what would the observer infer that our globe revolved on her axis, and the *time* of her rotation? From what the inclination of her axis? From what infer that she had an *atmosphere?* What said of zones, colors, &c.? Which figures on the map are representations of Mars? Have you noticed the several figures from 14 to 23, *by whom* the views were had, and *when?* How is this variety of appearance accounted for? What said of the bright spot, Fig. 22? What said of the *surface* of Mars? What says Dr. Herschel of this planet? Who constructed a *map* of Mars? What is his *color?* What is supposed to be the cause of this ruddy appearance? Can it be discerned by the naked eye? What said of our knowledge of the asteroids? Of the appearance of Pallas? Are the asteroids visible to the naked eye? What is their telescopic *color?* What does Fig. 24 represent? What is his color? Where are his *belts?* What are they supposed to be? What is their *number?* What said of changes in their forms? Of spots in them? Is the figure an exact circle? Why not?

65.—Subject? What does Fig. 25 represent? What said of Saturn's *belts?* His *rings?* Of the *color* of the planet and rings? How was Saturn regarded before the invention of the telescope? Have you carefully observed the different views at the top of the map from 1 to 12, and noticed what is said of them in the lesson? When, and by whom was the first view had? Through how long a period do these views extend? Where have we a correct representation of Saturn? What said of the different appearances of Saturn? Can you explain the *cause* of these different aspects of Saturn, and illustrate by the map? For what other purposes may this diagram be used? What is the *first* fact shown? Illustrate. What is the *second* point illustrated? How shown by map? What next does it show? Where are Saturn's *solstitial* points? His *equinoctial?* How may this diagram illustrate *declinations?* Why can we not see Saturn in the night at all seasons of the year?

66.—Subject? What is Saturn's diameter? The distance from the body of the planet to the interior ring? What is the width of this ring? What space between the two rings? What is the width of the exterior ring? The distance across the exterior ring? What is the *thickness* of the rings? What does Fig. 4 represent? What said of the stars? What does Fig. 5 represent? Describe its different parts. What does Fig. 6 represent? What additional particulars are stated by your author respecting the rotation of Saturn, the nature of his rings, their actual separation, uses, &c.? What said of spots upon Herschel? What said of his *atmosphere?* How does he appear through a telescope? What is his *color?* What said of Le Verrier? What does Mr. Lassel say of Le Verrier's having *rings* and a *satellite?*

67.—What is the subject of this lesson? Who discovered Mercury, Venus, Mars, Jupiter, and Saturn? Can you tell *when* and *by whom* the other planets were discovered? Who demonstrated the existence of the last new planet? What other astronomer was making similar calculations at the same time? Who first *saw* Le Verrier, and where? Can you explain what has been called "*Bode's Law,*" respecting the distances of the planet? How does the distance of Le Verrier compare with the distances of the fixed stars? What *part* of your book are you now in? What part of the solar system have you now gone over or considered?

68.—What is the subject of this *chapter?* What of this *lesson?* What are the *secondary planets?* What number is known to exist? How are they distributed to the several planets? Point them out on the map. In what respects do the secondary planets resemble the primaries? What purpose do they seem to answer in the economy of nature? What are they usually called?

69.—Subject? Is it probable that Venus has a satellite? What is its supposed *period, distance,* and *magnitude?*

70.—Subject? Why is our moon an object of great interest to us? What is her mean distance from the earth's centre? How long is she in making a *sidereal revolution?* A *synodic* revolution? What is her hourly motion in her orbit? Her mean angular motion per day? Her *diameter?* Her *angular* diameter? Her *bulk* as compared with the *earth?* As compared with the *sun?* What is the inclination of her *orbit* to the *ecliptic?* The inclination of her *axis* to the plane of her *orbit?* In what time does she rotate upon her axis? How much light does she reflect, as compared with the sun? Why does she appear as large as the sun? How does her distances compare with his? Do you remember in what ratio *distance* diminishes the apparent size of bodies? *Where* and *how* is this illustrated?

71.—Subject? What does the upper row of figures represent? Can you explain the *cause* of these various appearances of the moon, as seen from the earth? How would she appear to a person stationed in the sun? Explain the different figures from A to H. What are such a revolution and the consequent changes called? Where are the *syzygies*, *quadratures*, and *octants* in the moon's orbit?

72.—What does Fig. 2 on the map represent? Where are the *new* moons seen? Where are the *full* moons? Which in *conjunction*, and which in *opposition?* [56] How much of the moon is always enlightened? How many revolutions does the moon make in a year? What is a *lunar* year? How much shorter is it than the civil year?

73.—Subject? What are the *nodes* of a planet's orbit? Are the moon's nodes permanent in the ecliptic? What motion have they? To what does it amount every lunar year? How long, then, does it require for her nodes to revolve quite around the ecliptic?

74.—What is the difference between a *sidereal* and *synodic* revolution of a planet? Can you illustrate by any figure on the map?

75.—Subject? What fact respecting the moon is obvious to the naked eye? What four conclusions follow from this fact? How is it shown by the map that if the moon always presents the same side to the earth, she must revolve on her axis every 29½ days?

76.—Subject? What is meant by the moon's *librations?* What is her libration in *longitude?* What causes this rolling motion? What is libration in *latitude*, and how is it accounted for?

77.—Subject? What is the length of the moon's year? What said of her days and nights? Of the sun's declination upon her? Of her seasons?

78.—Subject? What does Fig. 4 represent? What is meant by the "*circle of illumination?*" What is the *terminator?* How does this line traverse the moon's disc? What are Figs. 5 and 6?

79.—Subject? What particular fact becomes obvious by observing the moon with a telescope? What three circumstances show the existence of lunar mountains? Can you illustrate by figures 4 and 6? What is the character of the lunar mountains? What did Dr. Herschel see? What is said of seeing cities, fortifications, &c., in the moon? Has the moon an atmosphere? How does she appear through the monster telescope of Lord Rosse?

80.—Subject? What is the average height of the nine principal mountains of the moon? Have you looked up *Tycho*, *Kepler*, *Copernicus*, &c.? Can you point out the principal *seas* upon her surface?

81.—Subject? How many moons has Jupiter? What are their *diameters* respectively? What their *distances* from Jupiter? What their *periodic times?* What resemblance is discovered between Jupiter's first moon and ours? What striking contrast? How does its velocity compare with that of our moon? How is this rapid motion accounted for? How do the orbits of Jupiter's moons lie? What is their inclination, respectively, to the plane of his equator? What is said of their eccentricities? In what direction do they revolve? What said in respect to the visibility of these satellites? What of Jupiter and his attendants as a whole? Can any member of the class point out each moon upon the map, and give their distances, magnitudes, and periodic times?

82.—Subject? How many moons has Saturn? How is this ascertained? In what direction do they revolve? What said of the *form* and *position* of the orbits of the first six? What of the seventh? Can you give their *distances*, respectively, from the body of Saturn? Can any of them be within the rings of the planet? [Compare with distance Lesson 66.] What are their periodic times? What said of their relative magnitudes? How are the two interior moons seen when the rings of Saturn are turned edgewise?

83.—Subject? How many moons has Herschel? Can you recite their respective distances from their primary? What are their periodic times? What two remarkable peculiarities distinguish the moons of Herschel? How is the latter indicated on the map? What is the general form of the orbits of these satellites?

84.—Subject? Is it probable that Le Verrier has one or more satellites? Have any ever been seen, and if so, by whom? What other circumstances seem to render the existence of such moons probable? Do the secondaries rotate upon their respective axes? Have *they* any attendants revolving around *them?*

85.—What is the subject of this *chapter?* What part of the solar system have you now considered? What is the subject of this *lesson?* What is an *eclipse?* A *solar* eclipse? A *lunar?* Where do we begin in explaining the philosophy of eclipses? What is a *shadow?* Upon what do the *length* and *form* of shadows depend? Illustrate by map. What would be the form of the earth's shadow if she were larger than the sun? When the opaque body is *smaller* than the luminous, how does its *distance* affect the length of its shadow? Illustrate by map. What difference between the *umbra* and *penumbra?* What, then, is the *cause* of a *solar* eclipse? Illustrate by map. Which limb of the sun is first obscured, and why? Illustrate. What causes *lunar* eclipses? Explain, by map, why the *eastern* limb of the moon is first obscured. Why are *solar* eclipses always at *new moon?* Why *lunar* at *full moon?*

86.—Subject? What is the first thing to be determined in calculating a solar eclipse? How does the place of the earth in her orbit affect the length of her shadow? Illustrate. Why are the shadows of the earth and moon longer at U, and shorter at T? How does the *moon's* position, in her orbit, affect *her* shadow? What is the *third* circumstance mentioned as affecting the length of the moon's shadow? When the earth is at U, and the moon in *perigee*, how far will her shadow extend? What will be its diameter at the earth's surface? What of the *penumbra?* When will the eclipse be *partial*, and when *total?* How is it when the sun and moon are both nearest the sun, as at T and U? How when the sun and moon are at their *mean* distances? Why do the sun and moon appear to vary in size? How must the sun and moon be situated, as to distance, for a central solar eclipse to be *total?* How long may a total eclipse of the sun last? When does the moon appear *smaller* than the sun? Should a central eclipse of the sun occur then, what would be its character? How long may the ring last in an annular eclipse? What is meant by "*digits?*" Do you now understand the cause of *partial, total, central*, and *annular* eclipses? What said of the eclipses of 1858, 1861, &c.? Of those of 1854, and 1875? Knowing the time of one eclipse, how can we find the time of others, either past or to come?

87.—Subject? What is the average length of the earth's shadow? How does this compare with the *moon's distance?* What its average *breadth* at the distance of the moon? What three circumstances are mentioned as affecting the *extent* and *duration* of lunar eclipses? Illustrate the last-named principle. Why is a lunar eclipse ever *partial?* Why are they *never annular?* Describe the *progress* of a lunar eclipse.

88.—Why do we not have two central eclipses every month? Illustrate. Where must the moon be for an eclipse to occur? Explain by Fig. 2. Must the moon be exactly on the line of her nodes? What are the solar and lunar *ecliptic limits?* To what do they amount respectively? How illustrated by Fig. 2? What singular motion have the moon's nodes? Illustrate. Why are we sure of an eclipse every one hundred and seventy-three days? What are the *node months?* What the least, and what the greatest number of eclipses per year? What the usual number?

89.—Subject? What causes the *occultation* of a *star?* What conclusions are drawn from these eclipses of the stars?

90.—Subject? Do all planets cast shadows? Why cannot the primaries eclipse each other? What said of the character of Jupiter's shadow? Of its position? Of the plane of his equator? Of the orbits of three of his moons? What said of the fourth, or most distant satellite? What is generally the case as to Jupiter's moons? About how many eclipses has Jupiter in a month? Are they usually *partial*, or *total*, and why? What said of the shadows of his satellites? What are the *immersions* and *emersions* of his moons? How are these eclipses made serviceable in navigation?

91.—Subject? Has Saturn any eclipses? Why confined to the time when his rings are seen edgewise? What said of Herschel's moons?

92.—What is the subject of this *chapter?* Which division of the book are you now in? What are the subjects of the chapters already gone over? What is the subject of this first lesson on tides? What are *tides? Flood* tide? *Ebb* tide? How many each day? What *causes* the tides? What does Fig. 1 represent? What does Fig. 2 illustrate? Fig. 3? How do you account for high tides on the side of the earth *opposite* the moon? Illustrate by map. What is the supposed amount of the earth's perturbation, as affected by the moon?

93.—Subject? Where is the vertex of the tide-wave generally found? How illustrated by map? What is the *cause* of this lagging, or delay? Why is high-water later and later every day? Why is every alternate tide higher than the intermediate ones, when the moon is far from the equinoctial? Illustrate by the map.

94.—Subject? Is the moon the *only* cause of tides? What is the comparative bulk of the sun and moon? Why, then, is not the sun the principal cause of tides? What is his influence upon the earth, in the production of tides, as compared with that of the moon? Would the sun *alone* produce a perceptible tide-wave? When both influences are united, what is the comparative *increase* of the tide-wave? When they *counteract* each other what is the result? What are these very singular tides called? What the low tides? When do the *spring tides* occur? When the *neap tides?* How illustrated by the map? When the sun and moon are *in opposition*, how are spring tides produced? Does your author seem satisfied with the usual explanation of this point? What objection does he name? What said of Professor Olmsted's explanation? What does Fig. F represent? What A and C? What B and F? Can you state Professor Davies' theory, and illustrate by the map? What says your author of this theory?

95.—How are our tides affected by the *distance* of the moon? Illustrate. What principle is illustrated at E? *What variations* in the height of the tides in different parts of the world, and *how caused?* What said of *local causes* detaining or hastening the tides? Of lakes and inland seas? Of *atmospheric* tides? Of tides on the *sun?*

96.—Subject? Define the *apsides* of the moon's orbit, and illustrate by map. What is meant by the "*motion of the apsides?*" Illustrate. In what time is an entire revolution completed? Has this motion any connection with *eclipses?*

97.—What is the subject of this *chapter?* What are the subjects of the chapters preceding? What is the subject of this *lesson?* What said of the *character* of comets? From what is their *name* derived? Of what *parts* do comets usually consist? Describe each. Have all comets a *nucleus?* Have they all *tails?* What says Cassini of the comet of 1682? What is the general *direction* of the tails of comets? Illustrate. What peculiarity in the comet of 1823, and how illustrated by map? How are the tails of comets usually curved? What is the *cause* of this curvature? Could a comet get through our atmosphere so as to strike the earth? What said of the comet of 1744? How shown on the map? What said of the *elongation* and *contraction* of the tails of comets? Of *sudden* expansions? Of the *physical nature* of comets? What *proofs* of their lightness from attraction? What was Sir Isaac Newton's opinion of their density? How are their *orbits* sometimes affected by the attraction of the planets? Are they self-luminous, or opaque bodies? What proof? Are they in reality "*fiery* bodies?"

98.—Subjects? What said of the comparative *size* of the *nuclei* of comets? Can you give the diameter of any? What said of the magnitude of the *tails* of comets? Of that of 371 years before Christ? Of A. D. 1618? Of 1680? Can you point out these comets on the map? Give the length of the tails of some of the most remarkable comets. Does the angular length of comets, as seen from the earth, show their true relative length? What said of the *velocity* of comets? What inequalities? When is their velocity *greatest?* When *least?* What was the angular velocity of the comet of 1472? [See lesson 10, and map.] What was the *hourly velocity* of the comet of 1680? What said of the *temperature* of comets when nearest the sun? What was the perihelion distance of that of 1680? What its relative *light?* Its *heat?* What supposition respecting the *production* of the tails of comets?

99.—Subjects? What is the *periodic time* of *Encke's* comet? Of *Biela's?* Of *Halley's?* Of the comet of 1680? When next to return? Have any still longer periods? Do all comets return to our system? Why not? What is Professor Nichol's opinion? Who concurs with him? What said of the *distance* to which some that return must go? What does this prove in regard to the distance to the fixed stars? What said of the *perihelion distance* of comets? How were the perihelion points of the one hundred and thirty-seven comets mentioned distributed? What said of the *number* of comets? What circumstances render it probable that their number amounts to millions? What was Professor Arago's conclusion, and from what premises?

100.—What said of the *direction* of comets? What says Professor Kendall of their inclinations? How is this circumstance regarded by him? What is the usual *form* of the comets' orbits? Why not seen longer from the earth? How were comets formerly regarded? Are they *dangerous* in the solar system? Is a collision with the earth probable? What are the *chances* for such a catastrophe? What would be the result, if they should strike our globe? What is Professor Olmsted's opinion?

101.—Of what does this *chapter* treat? What is the subject of this particular *lesson?* What said of the *position, office,* and *comparative importance* of the sun? What is his *diameter?* How illustrated by *tunnel,* and *railway?* How does his diameter compare with that of the earth? How his *mass?* How with the whole solar system besides? How is the subject of his magnitude illustrated by reference to the moon's orbit? What is the true *form* or figure of the sun? Illustrate his relative diameter by the map.

102.—Subject? What does the telescope reveal upon the sun's disc? What said of their *number?* Are spots always visible? What is the greatest number ever visible? What says your author of his own observations?

103.—Subject? What is the appearance of the solar spots? Point out a *nucleus,* and its penumbra, on the map. Can you name some of the principal phenomena of the solar spots? What did Professor Henry ascertain? What was Lalande's opinion? What thought Dr. Herschel of this suggestion? What was Herschel's opinion? What said of tides on the sun? To what conclusion did Professor Wilson arrive?

104.—Subject? What view of the sun is shown on the map? What said of Dr. Herschel's observations and statements? Of Dr. Dick's views? What does he infer from the fact that spots have been seen by the naked eye? What says your author of this conclusion?

105.—Subject? What is the inclination of the sun's axis to the ecliptic? What *proof* have we of his revolution on his axis? In what *direction* does he revolve? In what *time?* What difference between his *sidereal* and *synodic* revolutions? How do you account for this difference of time?

106.—Subject? In what direction do the solar spots cross the sun's disc? How, then, can he revolve from west to east? How illustrated by two spheres? What said of the apparent inequality of motion of the solar spots? How explained, or accounted for? How illustrated by Fig. 1? Explain their change of *figure* by the map.

What changes in the apparent *direction* of the spots at different seasons, and how explained and illustrated by the map?

107.—Subject? Is this subject well understood? How does the sun appear through a telescope? What was La Place's opinion concerning it? What is the most probable opinion? What says Dr Herschel of the *temperature* of the sun? What calculation in reference to the light and heat of the sun's surface? What remark in regard to ignited solids? What does Dr. Herschel infer from this? Does his conclusion *necessarily* follow? What says he of a *reflective canopy*, &c.? What does he consider the great mystery in regard to the sun? Does chemical science throw any light upon this question? What does Dr. Herschel conjecture?

108.—Subject? What is meant by the *zodiacal light?* What is its *form?* How does it seem to surround the sun? With what does its shape seem to correspond? How, then, do we account for its *apparent* shape as seen from the earth? What said of the *nature* of this substance? What is Professor Nichol's opinion? What says Dr. Herschel? What say Dr. Dick and La Place upon this point? What are the *dimensions* of this phenomenon, as given by Dr. Herschel? What other opinion is advanced respecting the zodiacal light? What says Professor Olmsted? Who concur with him in this opinion? Which are the best months for observing this phenomenon? What interesting fact is stated by Professor Nichol? What does this seem to indicate?

109.—Subject? What astonishing fact has been ascertained respecting the sun? How many motions has he? What is the *first?* The *second?* The *third?* Who ascertained the *direction* and *velocity* of the sun? What is the point of tendency? What is the estimated *velocity* of the sun? With this fact in view, how should the sun be regarded? What still more magnificent idea? What further light is thrown upon this interesting subject? Who has the credit of discovering the "*central sun?*" Where does he locate the centre of our cluster of suns? What star does he fix upon as the central orb? What is the supposed distance of Alcyone, as compared with that of our sun? How does this distance compare with that of Le Verrier? How long would light be in traversing this distance? What is Mädler's estimate of the *periodic time* of the sun? Of his *velocity?* How does the plane of the sun's orbit lie, with respect to the ecliptic? Where the *ascending node* of his orbit?

110.—What is the subject of this *chapter?* Of this particular lesson? Can you describe what is called the *nebular theory?* Who originated this theory? What circumstances seem to favor it? Is it open to any serious objections? What is the *first?* What is the *second* objection? The *third?* The *fourth?* The *fifth?* Do any regard this theory inconsistent with the Mosaic account of creation? What is the opinion of your author?

111.—Subject? How many principal laws that govern planetary motions? What called, and why? What is the *first* of these laws? What is an *ellipse?* What is meant by the *major*, or *transverse axis* of an ellipse? What are the *foci?* What is the *radius-vector?* [See map 7, Fig. 1.] What is the *second* law of Kepler? Can you illustrate this law by the map? What is the *third* law? Can you illustrate by an example? Does this law prevail throughout the solar system?

112.—Subject? In this illustration, what is the relative diameter given to the sun? Mercury? Venus? Earth? Mars? The Asteroids? Jupiter? Saturn? Herschel? Can you give any of the *distances* according to this representation?

113.—What is the question discussed in this lesson? What *suspicion* was entertained before the discovery of the asteroids? Upon what was it based? What influence had this opinion upon astronomers? What opinion has been advanced in respect to the *origin* of the asteroids? What six facts are supposed to favor this hypothesis? To whom does this theory belong? What other astronomers favor it? What says Dr. Herschel of it? What remark by Dr. Dick? What new theory by General Root? What does your author think of Dr. Olber's theory, and why?

114.—What question is discussed in this chapter? Have we any direct testimony upon this subject? Upon what, then, is the argument based? What is requisite to a full appreciation of this argument from analogy? What facts, then, seem to require that the planets should be inhabited? The first? Second? Third? Fourth? Fifth? Sixth? Seventh? Eighth? Ninth? What argument from the animal inhabitedness of all parts of our globe? What part of the universe, and of your book, have you now gone over? What yet remains to be considered? What is meant by the *solar system?* What by the *sidereal heavens?*

115.—What is the subject of Part II.? Of this first *chapter?* Of this particular lesson? What four characteristics are mentioned as distinguishing the fixed stars?

116.—What is the first step in classifying the stars? What the *second?* How many magnitudes? Which are visible to the naked eye, and which telescopic? Illustrate by map. Does this classification indicate their *actual* relative magnitudes? Why not? What is the *third* step in classifying the stars? How are the individual stars in each constellation designated? What is the *fourth* help in finding and numbering stars? The *fifth?* Can you give the *names* of any stars? Can you name any *clusters?* How are the stars still further distinguished?

117.—Subject? Is it possible to determine the actual number of the fixed stars? What is the estimated number visible to the naked eye? Can you give the numbers of each of the first six magnitudes? What is the estimated number visible through telescopes? Can you recite the number of each magnitude from the seventh to the twelfth inclusive? What is the entire number of all magnitudes? What remark of Dr. Herschel? Of Professor Olmsted? What estimate respecting the number of worlds in our firmament? How do all these compare with the boundless universe? What idea is advanced in regard to the employments of the Christian in a future state?

118.—Subject? What is the estimated *distance* of the nearest fixed star? How long would light be traversing such an abyss? How many times its present distance must such a star be removed to appear only of the twelfth magnitude? What astonishing conclusions follow from these premises?

119.—Subject? What inference respecting their *magnitudes* from their *distances?* Is it probable that the stars are of uniform size? What opinion prevails among astronomers respecting them? How many times his present distance must our sun be removed to transmit no stronger light than Sirius? How far off would that be? How much less than the distance of Sirius? If, then, the light of Sirius would equal that of our sun, though seven millions of miles farther off, what must be his relative magnitude and splendor? What does Dr. Wollaston conclude respecting this star? What is the magnitude of *Vega* in the Lyre, as compared with the sun? Of 61 in the Swan? What interesting circumstance is mentioned respecting Sir John Herschel and Sirius? Can you give the relative light of the stars of the first six magnitudes?

120.—Subject? What are constellations, and what was their *origin?* What said of their *antiquity?* What proof? What said of their *number* at first? Is there room for any additional constellations? How are the constellations divided, or classified? Which are the *zodiacal?* Which the *northern?* Which the *southern?* What other distinction of the constellations? Can you name the *zodiacal* constellations? What is their number? How many *northern* constellations are there? Of these, how many are modern? Can you name any of the northern constellations? What is the number of *southern* constellations? How many ancient? Modern? Can you name some of the southern constellations? Can you recapitulate the number of constellations in each division, and the total number? What is the total number of principal stars? [This number is 1917 less than the number given as visible to the naked eye, in the table 117; but one table includes only the "*principal*" stars, while the other embraces all that are "*visible.*"]

121.—Subject? Upon what *atlâs* is the student to trace the constellations? How are the zodiacal constellations arranged? How may *Aries* be known? How find *Taurus?* What said of the largest star in this constellation? What are the *Hyades?* Of their arrangement? How may *Gemini* be known? What said of *Cancer?* For what distinguished? For what is *Leo* remarkable? What is the *name*, magnitude, and *position* of his largest star? In what manner are his other stars arranged, and where, in this arrangement, is Regulus? What other star is named, and what is its magnitude and position? Describe the next constellation. What star is named, where is it found, and what its magnitude? What said of the remaining stars? How may *Libra* be known? What constitute the *beam* of the scales? Where is the smallest of the four stars? What said of *Scorpio?* Of his head? Of his relation to the ecliptic? What star is named, and what said of its position, color, and magnitude? Where does *Capricornus* lie, and how may it be known? How is *Aquarius* represented? What are the magnitudes of his four largest stars? How find the *head* of the figure? Describe Pisces, their position, number of stars, &c. Where is the largest star situated, and what is its *name* and *magnitude?*

122.—Subject? Where do we begin this review, and in what direction do we proceed? How may *Andromeda* be known? Describe the figure. What said of the middle star? Of the one west of Mirach? Of the *eastern* one? What said of the position of Mirach in respect to the Colures? What of the *size* of the three principal stars? Of the girdle of Andromeda? What directly south of Mirach? Where is *Perseus* situated? What is the figure? Where is *Algol* situated, and what is its magnitude? What star *east* of Algol, and how far? What other stars are mentioned? What is the figure of *Auriga*, his posture, and position? What said of his principal star? Where situated, and how known? Where is the *Lynx* situated, and what said of its component stars? Of what is *Leo Minor* composed, and where situated? What said of *Coma Berenices*, its situation, and principal star? What of Charles's Heart? What is the figure of Bootes? What large star in this constellation, his magnitude, situation, and color? What said of his "sons?" What other principal stars in Bootes? Where is *The Crown* situated? Of what does it consist? What is the position, magnitude, and name of the largest star? How else known? Where is Hercules situated? What the figure? How placed? Describe this constellation. Where is *Ophiuchus* situated? Describe the figure. What constitute the *head* of the serpent? How trace the *folds* of the serpent? What is the *name* and *magnitude* of the principal star in this constellation? Where is it situated? For what is *Aquila* conspicuous? What is the *name*, *position*, *magnitude*, and *appearance* of its principal star? Where, with respect to the Eagle, does the constellation *Antinous* lie? Where is the *Dolphin* situated, and how may he be known? How is Pegasus situated, and how described? How may he be known? What said of their magnitudes, &c.? Where is the *Horse's Head* situated, and how described?

What Constellations are next to be considered? Where is *Ursa Minor* situated? Of what does it consist? In what form are the seven principal stars arranged, and where is the Pole Star? How may *Ursa Major* be known? How many stars in the Dipper? What part of the Bear do they constitute? Can you name any of these stars? For what is *Mizar* remarkable? Which are the *Pointers*, and why so called? Where does the *head* of the Great Bear lie, and of what composed? What said of his feet? What said of the *extent* and *situation* of *Draco?* How may he be traced? By what may his *head* be identified? What is the magnitude of his principal stars? Where does *Cepheus* lie? Has he any conspicuous stars? Describe the figure. How is *Cassiopeia* represented, and how situated? Of what is her *chair* composed, and what are their magnitudes? For what is *Lyra* distinguished? Where situated? What is its principal star called? What is its magnitude? What other stars in this constellation? Where is *Cygnus* situated? Describe its principal stars. Give the *name*, *place*, and magnitude of the largest of the group. What said of the remaining stars? Where is *Camelopardalus* situated? What said of its character? Of its principal stars? Where is its *head* situated? Of what is the *Lynx* composed? Where situated? Its three largest stars are how large?

123.—Subject? What general remark respecting the southern constellations? What is the comparative magnitude of *Cetus?* Where situated? How placed? How may his *head* be known? Give the name, place, and magnitude of his largest star. Where is *Orion*, and what said of him? What is the figure? How many principal stars? What stars form the *shoulders?* The *head?* The *belt* or "bands?" What other name have they, and why? What constitutes his *sword?* What are the belt and sword together sometimes called? Which star is called *Mintika*, and near what is it situated? Where is *Rigel*, and what his magnitude? *Saiph*, and his magnitude? Where may *Lepus* be found, and how known? What is the name and magnitude of his principal star? Where does the *Dove* lie? How many visible stars? Name the brightest, and next brightest, and give their relative positions. How may *Beta* be known? What is the direction of *Eridanus?* Its length? How divided? Where does the southern begin and terminate? [The *southern* stream is a continuation of the northern, which forms a bend near Cetus, and passes off southeasterly towards the Dove, and then flows to the southwest till it disappears. *Rigel*, in Orion, is in this stream. Its remaining stars are mostly of the third magnitude.]

Where is *Canis Major* situated? How found? What said of *Sirius?* Where may *Canis Minor* be found? What principal stars, their names, and magnitudes? Where is *The Unicorn* located? What is the magnitude of his principal stars? How may his *head* be found? Where may the head of *Hydra* be found, and how known? What star in his heart, his position, and magnitude? Where is *The Crow* situated, and how represented? What number of visible stars, and their magnitudes? What said of *Argo Navis?* How situated? How known? Where is the star *Markeb?* What stars of the second magnitude? What of the first? What said of *Centaurus?* Of *Lupus?* Where is *Sextans?* What is the size of its largest star, and how situated? What said of *The Cross?* Its situation, and component stars?

124.—What is the subject of this *chapter?* Of this *lesson?* What meant by *double, triple,* and *multiple* stars? What other names for the same things? In what two ways are stars supposed to be rendered double? Are these companionships more frequent than could result from accidental causes? What does Fig. B represent? What said of their color and magnitudes? Why an interesting double star? What does Fig. C represent? What said of the *colors* and *magnitudes* of its component stars? What is their distance from each other? What does Fig. D represent? Their magnitudes? Distance apart? Their *colors?* What said of this star as a *test object?* Of what is Fig. E a representation? What is the *color* of these stars? What their magnitudes, and distance asunder? What estimates have been made of the *number* of double stars? What first led astronomers to suspect the physical connection of double stars, and their periodical revolution?

125.—Subject? What are *Binary systems?* How were their revolutions detected? What said of the periods of those best known? What double star is mentioned, and where found? When first noticed? What is their periodic time? Their angular motion? What curious calculation has Dr. Dick respecting these stars? What system is represented at Fig. G? What is its probable period? What does Fig. H represent? Can you give their *period, color,* and *magnitudes?* In what light should these systems be regarded? What says Dr. Dick of them? What said of their proper motions in space? What is the supposed cause of the variety of colors they present? Is it probable that the colors are merely complementary in all cases? What said of isolated red stars?

126.—Subject? What are *variable stars?* What is the character of their variation? How is the term "*period*" applied to variable stars? What two remarkable periodic stars are mentioned? Where is *Mira* situated? What said of its variations? Where is *Algol?* What said of its variations, period, color, &c.? What is the supposed *cause* of these periodic variations? What says Professor Olmsted? What other theories to account for these variations? What remarks by Mr. Abbott?

127.—Subject? What are *temporary stars?* What said of Hipparchus? What of the temporary star of 389? Of that of November, 1572? What remark by *Mrs. Sumerville?* What observation by *Dr. Dick?* What opinion by *Professor Vince?* What say *La Place,* and *Dr. Goode?*

128.—Subject? What said of introducing this subject here? What are the falling or shooting stars? When great numbers fall, what are they called? When did the most remarkable of these occur, and how described? From whence are these meteors supposed to come, and how ignited? How does Professor Olmsted account for them?

129.—Subject? Give the *names* and *places* of some of the clusters. For what sometimes mistaken? What list has been formed, and what said of it? How known to be *clusters,* and not *comets?* What said of the *forms* of these clusters? What said of the number of stars they contain? What said of Fig. I, and of red stars? What said of the probable *nature* and *distances* of the individual stars of these clusters? What does their globular figure indicate? What further said of J and K? Of a new cluster?

130.—Subject? To what is the term *nebulæ* applied? What are *resolvable* nebulæ? What *irresolvable?* Is it likely that any nebulæ are actually irresolvable? What evidence from Lord Rosse's observations? Where is the newly discovered *spiral nebula* situated? What resemblance to our Milky Way? What does this nebula resemble? Is this, too, composed of individual stars? Describe Fig. L on the map. What said of *single* and *double* nebulæ? What specimen given, and where found? What specimen of *hollow nebulæ,* and where found? What are *stellar nebulæ?* What specimens, and where found? What said of the *sun* and *zodiacal light?* What are *planetary nebulæ?* What said of their *magnitude?* What illustrative specimen? What are *annular* nebulæ? [See *annulus,* in the Appendix.] Where may the most conspicuous be found, and how described? What does Fig. R represent? Fig. S? What does Fig. T represent? What said of the *number* of nebulæ? What is "*star dust?*" Illustrate appearance by the map. What illustration of the uses and powers of the telescope from this map? What is the object of this experiment? What says Sir John Herschel of the nebulæ? What said of the *Milky Way?* How illustrated by map? Why, then, appear so extended? How would it appear to an observer as far off as the nebulæ in the Lyre? May, therefore be called what? What is Mädler's conclusion in respect to the structure of our stellar firmament? What estimate by Sir W. Herschel relative to the *number* of the fixed stars? What said of their probable *mutual distances*, positions, and offices? What idea of the extent of the universe drawn from the dimensions of our own cluster, and the number of clusters in remote regions? What closing reflections are subjoined by your author?

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